Review of Nonpoint Source Pollution and Best Management Practices Along the South Carolina Coast

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REVIEW OF NONPOINT SOURCE POLLUTION AND BEST MANAGEMENT PRACTICES ALONG THE SOUTH CAROLINA COAST

Introduction

Studies of nonpoint source pollution, the legal aspects of storm water legislation, and urban best management practices were reviewed to determine that the best techniques are being used to control nonpoint source pollution in Charleston and other coastal areas. Comprehensive information was obtained through literature reviews at Clemson University's Cooper Library, attendance at The American Society of Civil Engineers (ASCE) Water Forum 1992, attendance at the South Carolina Land Resource Conservation Commission (SCLRCC) workshop "Site Development and Best Management Practices for Stormwater Management and Sediment Control", and personal communications with relevant specialists. Contacts to obtain unpublished and/or up to the date resources include:

- MaryAnn Gerber, Environmental Engineer - United States Environmental Protection Agency (USEPA) Region IV Water Management Division, nonpoint source specialist.
- Marshall Jennings, Civil Engineer/Hydrologist - United States Geological Survey, Water Resource Division, Texas District, detailed knowledge of Nationwide Urban Runoff Program (NURP) studies.
- Earl Shaver, Environmental Engineer, State of Delaware, Division of Soil and Water Conservation, Department of Natural Resources and Environmental Control, pioneered practical design storm water management and erosion control aspects - while at Maryland in a similar position.

- Joe Fersner and Debra Hernandez, Hydrologists/Environmental Engineers - South Carolina Coastal Council, special knowledge of codes, and management practices specific to the coast of South Carolina.

- Chuck Jarman, Capital Project's Engineer, Charleston County, SC, design expertise of coastal best management practices.

- Flint Holbrook, Hydrologist/Civil Engineer, South Carolina Land Resource Conservation Commission, close knowledge of best management practices for storm water management and sediment control.

- Larry McDonald, South Carolina Department of Health and Environmental Control, nonpoint source pollution expert.

- Paul Conrads, Civil Engineer/Hydrologist, United States Geological Survey, Water Resource Division, South Carolina District, coordinator of water quality studies for calibration and verification of water quality models of the Charleston Harbor.

NONPOINT SOURCE POLLUTION

Introduction

Water quality is altered when pollution enters the water. Pollution is defined as a contaminant that has a detrimental effect on the environment. Two types of pollution exist, point and nonpoint source. Point source pollution is defined as pollution discharged from a well-defined location, such as discharges from industrial processing waters or the effluent from sewage treatment facilities. Nonpoint source pollution, the subject of this investigation, is defined as pollution occurring from an ill-defined or diffuse source (SCLRCC 1989).

In 1978, the United States Environmental Protection Agency (USEPA) began a 5-year study of storm water. This study was called the Nationwide Urban Runoff Program (USEPA 1983). The study found that in rivers and streams, the heavy metals water quality criteria for aquatic life is frequently exceeded because of urban runoff. From the analysis of heavy metals, copper, lead, and zinc typically had the highest concentrations. Copper, lead, and zinc, with copper being the most troubling, pose the biggest threat to aquatic life. The study looked at only two sites regarding organic priority pollutants (e.g. pesticides). For this reason, priority pollutants were generalized as being detected less frequently and occurring at lower concentrations than heavy metals.

Nutrients, i.e. total phosphorous, soluble phosphorous, total kjeldahl nitrogen, nitrate, and nitrate were carefully examined. Results indicated that nutrient concentrations in urban storm water runoff occurred at lower rates than in the receiving waters. The study indicated that some sites did record higher values, but this trend was atypical. Some lakes and streams became eutrophic when the nutrient levels were high in urban runoff. Oxygen demanding substances, in urban runoff, were indicated as being present in similar concentrations as effluent from sewer treatment plants using secondary treatment operations (USEPA 1983).

Total suspended solids concentrations in urban runoff occurred at fairly high levels when compared with sewage treatment plant effluent (USEPA 1983). Suspended sediments, from scour and erosion, were found to cause significant habitat disruptions in rivers and streams (Schueler 1987). Coliform bacteria were found to be present in high levels in urban runoff (USEPA 1983). USEPA water quality criteria for fecal coliform was typically exceeded during and immediately following storm events in most rivers and streams.

Based on data from only two sites, groundwater aquifers that received deliberate recharge from urban storm water runoff were not contaminated (USEPA 1983). Further studies should be conducted on the effects of infiltration practices on groundwater aquifers. Travel time to an aquifer is dependent on numerous parameters, (i.e. soil type and layer configurations, depth to bedrock, depth to groundwater table, etc.) which can vary locally and/or regionally.

Congress passed the **Federal Water Pollution Control Act Amendments of 1972** to allow US EPA and the States to control point source pollution with a permitting process called the **National Pollutant Discharge Elimination Systems** (NPDES) permit. The NPDES permit allows the permittee to discharge their point source pollutants as long as it meets the limits established by the permit. The presence of nonpoint source pollution is much harder to detect and regulate, some exceptions do exist (e.g. pesticide application for agricultural practices, etc.).

In November of 1990, Congress approved legislation that requires urban areas and industrial sites to have NPDES permits for all large storm water outfalls. Urban areas are defined as cities with populations greater than 100,000 people and/or counties with greater than 250,000 people. Large outfalls are defined as 36 inch (914.4 mm) or greater diameter pipes for cities and counties, and 12 inch (304.8 mm) or greater diameter pipes for industrial sites (USEPA 1990). Urban area and industrial site storm water runoff is the only nonpoint source pollution that is currently being regulated by NPDES permits.

To improve water quality, by reducing nonpoint source pollution, Congress passed legislation, Section 319 of the **Clean Water Act Amendments of 1987**, which required each state to assess nonpoint source pollution problems and develop a four-year management program for correcting the problems (SCLRCC 1989). The next section will address the problems South Carolina, and the United States, are facing with poor water quality caused by nonpoint source pollutants.

Current Policies in South Carolina

In South Carolina, the agency that is primarily responsible for water quality is the South Carolina Department of Health and Environmental Control (SCDHEC). In addition, the South Carolina Land Resource Conservation Commission (SCLRCC), the South Carolina Coastal Council (SCCC), and the South Carolina Forestry Commission (SCFC) have some water quality responsibilities. These agencies are working in collaboration to comply with the Section 319, of the **Clean Water Act Amendments of 1987** (SCLRCC 1989). In a survey of nonpoint source pollution, the above South Carolina agencies found a total of 336 water bodies (e.g., lakes or ponds) in South Carolina had been impacted. Of these 336 water bodies, 43% were influenced by storm water runoff and another 14% were influenced by construction activities. Forty-seven of those water bodies were determined by SCDHEC to be of top priority (SCLRCC 1989). Data from SCDHEC shows approximately 390 sources of pollutants contaminated the groundwater at thirty-five sites, with about 90% clearly associated with nonpoint source pollution. After assessing the effects of nonpoint source pollution on water quality, SCDHEC has and is forming a plan of action.

A bill sponsored by SCLRCC has made parts of SCDHEC's plan of action become state law. The bill was introduced in the 1989 session of the South Carolina General Assembly (passed and recorded in South Carolina State Register, June 26, 1992). The bill requires all land disturbing activities to be conducted in accordance with storm water management and sediment control plans approved at either the local or state level. Specifically, the bill states that "... [site] plans should include measures for storm water management and sediment control during the land disturbing activity, as well as the maintenance of storm water systems throughout the life of the facility (SCLRCC 1989)." To avoid delays in construction, the bill allows 15 working days for the administering agency to take action on applications, if no action is taken within the 15 working days the plan would become automatically approved. For more information, see the section entitled "Legal Aspects of Storm Water - Current Regulations."

Another part of the plan of action required SCDHEC to write a manual called **Nonpoint Source Management Program for the State of South Carolina.** In this manual SCDHEC established nonpoint source pollution management goals for: agriculture, forestry, construction, urban runoff, mining, land fills, and hydrologic/wetlands modifications. These goals are referred to as best management practices. SCDHEC defines best management practices as storm water management and conservation practices which have been demonstrated to effectively control movement of pollutants, prevent degradation of soil and water resources, and are compatible with the planned land use (SCDHEC 1989b). Also in the manual, SCDHEC states that at the time of writing the manual, more research needed to be done to establish best management practices. SCDHEC stated their belief that a standard method of devising best management practices for all situations could not be provided (SCDHEC 1989b). Furthermore, SCDHEC predicts that education regarding nonpoint source pollution is an important tool in reducing nonpoint source polluting, thereby improving water quality.

Nonpoint Source Pollutants in South Carolina

South Carolina is a state with diverse topography and land use. South Carolina's economy relies on agriculture, construction, industry, forestry, mining, textiles, and tourism. All of the above can contribute nonpoint source pollution that has a negative effect on water quality. The following list is characteristic of nonpoint source pollutants (or measurements of contamination) common to South Carolina's water (SCDHEC 1989a).

Dissolved Oxygen
Suspended Solids
Turbidity
pH
Fecal Coliform
Biochemical Oxygen Demand
Ammonia
Total Phosphorus
Nitrate-Nitrite
Conductivity
Iron
Lead
Cadmium
Chromium
Zinc
Nickel
Copper
Mercury
DDT
Aldrin
Endrin
Dieldrin
Toxaphene
Heptachlor
Malathion
Diazinon
Phosdrin
Acid Extractable Organics
Volatile Organics
Guthion
Trithion

Agriculture

Agriculture can contribute several different types of nonpoint source pollutants that will alter water quality. Pesticides are used extensively in farming operations. The pesticides then become nonpoint sources of pollution when they are carried to nearby lakes, rivers, or streams during a storm event. Pesticides also migrate through the ground to contaminate groundwater. Agriculture, in South Carolina also consists of raising livestock and poultry. The waste from the animals can act to contribute nonpoint source pollution in storm waters and groundwater. The animal waste is transported into nearby lakes, rivers, and streams during storm events, or infiltrates into the ground to contaminate groundwater supplies. An example of this type of nonpoint source pollution would be the runoff during a storm event that occurs at feed lots or pasture lands (SCDHEC 1989b).

Industry

Industry helps to create nonpoint source pollutants by the emission of point source pollutants into the atmosphere. These emissions are legal but when they are combined with car exhaust, smoke from homes heating with wood stoves, trash fires, forest fires, volcanic eruptions, etc., they form air pollution. When these pollutants become heavy enough, they settle out of the air (like regular dust particles). If moisture is present, the pollution particles will be the nuclei for water droplets. The pollution particles then fall to earth as "acid rain" or "acid fog."

Forestry, Construction, and Mining

South Carolina has a relatively large amount of timber lands available as forest resources. Current forest operations contribute vast quantities of sediment, which in turn degrades water quality. The sediment is transported into lakes, rivers, and streams by erosion during a storm event. Forest operations, agriculture, construction, and mining activities are significant contributors to erosion. For every pound of municipal and industrial waste discharged into our rivers, lakes, and streams, erosion can add several pounds of sediment (USDI/GS 1981).

Controlling Nonpoint Source Pollution

Nonpoint sources of pollution are very hard to locate. This makes a prescribed solution impossible to develop. SCDHEC has decided the best way to control nonpoint source pollution in South Carolina is through education and the implementation of best management practices (SCDHEC 1989b). It is much less expensive to prevent nonpoint source pollution from reaching the water bodies, than it is to treat compromised water bodies to improve water quality.

Some of the educational tools SCDHEC plans to use to disseminate information includes (SCDHEC 1989b):

- The publishing of a nonpoint source pollution control newsletter will be used to inform engineers, environmentalists, and other professionals of "current events" or research associated with nonpoint source pollution.
- A citizen's handbook on nonpoint source pollution is also to be written.
- Plans for seminars and conferences directed at the problems and available solutions for nonpoint source pollution are being made.

- The creation of films, slide shows, and videos targeted to different audiences (adults, children, and youth) should prove useful in detailing the problems and solutions associated with nonpoint source pollution.
- Exhibits and displays at county and state fairs would disseminate information to individuals that were still unaware of the problems and solutions that transpire with nonpoint source pollution.

The other tool SCDHEC has implemented to improve water quality is best management practices. Best management practices for protecting water quality in South Carolina are divided into seven categories by SCDHEC (1989a).

1) Agricultural Activities

- avoiding the spray of pesticides within eighty feet of water bodies
- contour farming
- field borders (that control erosion)
- crop rotation
- grassed waterways
- planned grazing systems
- strip-cropping, and terraces

2) Forest Activities

- better planning of access roads to control erosion
- better harvesting techniques that curb erosion
- service and maintenance of equipment should be performed far away from water bodies (as well as disposal of waste oil and lubricants in a legally designated manner)
- during site preparation make every reasonable effort to leave topsoil in place

3) Construction Activities

- temporary gravel construction entrance/exit (removes mud from construction vehicles before leaving the site as well as stabilizing the entrance from eroding)
- hay bale barriers
- silt fences
- rock check dams
- rip rap lined storm water outfalls
- dust control (use a water truck when dry weather is causing dust problems

4) Urban Storm Water Runoff

- grassed lined swales (typically with 4 horizontal : 1 vertical side slopes)
- rip rap lined ditches
- oil and grease filtering catch basins
- parking lot planting areas
- detention/retention/sedimentation ponds
- pervious asphalt paving
- rock check dams
- silt fences
- hay bales
- street flushing
- street cleaning

5) Mining Activities

- aquifer recharge systems
- buffer zones between mining activities
- contour mining
- controlled drainage
- dust suppressants
- sediment basins with flocculant settling
- geotextiles
- grassed waterway outlet structures
- neutralization
- mulching
- terracing

6) Solid Waste Disposal Activities

- proper landfill placement
- proper operation and maintenance (O&M) plan
- control of runoff and leachate
- incineration with resource recovery
- recycling
- proper erosion control plan
- buffers between landfill and water bodies
- groundwater monitoring

7) Hydrologic/Wetlands Modifications

- select previously used disposal sites
- mix, dilute, and disperse the discharge
- minimize water column turbidity
- avoid changes in water current and circulation patterns
- avoid seasons or periods when human recreational activity associated with the aquatic site is most important

LEGAL ASPECTS OF STORM WATER RUNOFF

History

Riparian Rights

South Carolina water law predates the formation of the United States. Much of South Carolina's water laws have a traceable history that originated in English Common Law. Water rights in South Carolina are based on the Doctrine of Riparian Rights. Riparian Rights are defined as the rights of owners of land adjacent to water bodies (i.e. rivers, streams, ponds, lakes, etc.) to use the water in that water body. The phrase, the right to use, is a keyword for understanding Riparian Rights. All adjacent land owners have the right to use the water in reasonable amounts but the water can not be used to the detriment of other adjacent land owners. Also, there is no priority for the right to use between land owners adjacent to the water body. Omelvany v. Jaggers, 2 Hill 634 (SC 1835); White v. Whitney Mfg. Co., 60 SC 254, 38 SE 456 (1901); United States v. 531.13 Acres of Land, 366 F.xd 915 (1966); and The Riparian Rights Doctrine in South Carolina, 21 SC Law Rev. 757, 770 (1969) are important precedents defining water rights.

Diffuse Water Rights

Diffuse water is defined as runoff water from precipitation, be it snow, sleet, freezing rain, or rain. The statutory regulations controlling diffuse water rights are defined in the **South Carolina Code of Laws §49-3-40** as follows. Diffuse water, in general, can not be confined to establish a stream. Water on land, can be used by the owner, conventionally. Runoff is treated as a "common enemy". The Common Enemy Doctrine allows a land owner to divert runoff so as to protect property. This diversion, however, can not be to the detriment of other land owners (Chapman, 1992).

Irrigation drainage systems are regulated by the **South Carolina Code of Laws §49-13-10**. The regulation of ground water is covered in the **South Carolina Code of Laws §49-5-10 and §49-5-20**. The regulation of wetlands is covered in the **Clean Water Act Amendments of 1987, Section 404** and/or 33 USC 1341 (Chapman, 1992). The regulation of storm water management is covered by R.19-450 (SCLRCC 1992). Regulations pertaining to critical areas of the coastal zone are covered in R.61-101.

Current Regulations

In South Carolina, the newest and most important regulations for storm water runoff appeared June 26, 1992 in the State Register. They are entitled, **Standards for Storm Water Management and Sediment Reduction.** These laws were prompted by the passage of the United States **Clean Water Act Amendments of 1987**. The **Standards for Storm Water Management and Sediment Reduction** establish a procedure and minimum standards required for a statewide uniform program for storm water management and sediment reduction with the option of being operated locally. The regulations are based on permits issued from site plan review and later investigations, which are made to determine that the approved site plans are being followed.

The regulations require that after October 1, 1992, all land disturbing activities greater than 2 acres must meet the minimum standards described in the regulations. If a local agency does not exist as of October 1, 1992, the South Carolina Land Resources Conservation Commission will assume the responsibility as the implementing agency. In South Carolina coastal counties, the South Carolina Coastal Council is vested with this responsibility. Along the coast, any land disturbing activity with in 1/2 mile of a receiving water body is required to receive a permit. There are some small counties that will be allowed to "continue as normal" until fiscal year 1994-1995.

In the **Standards for Storm Water Management and Sediment Reduction** §72-307 states that best management practices should be used to control sediment and water quantity/quality. §72-307 C) 4 a) states that, "Post-Development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10 year frequency 24-hr duration storm event." This parallels results obtained from studies by the Maryland Water Resource Administration (MWRA) and other leading agencies. A modeling analysis was used in which MWRA determined that if both the ten-year and two-year design storm events were used in the design of best management practices, then the whole range of expected storm reoccurrence intervals could be adequately controlled (MD WRA 1986).

CATEGORIES OF URBAN STORM WATER BEST MANAGEMENT PRACTICES

There are two categories of urban storm water best management practices - structural and nonstructural. A structural best management practice is one that must be constructed. An example of structural best management practices is the construction of a detention/retention pond to control storm water runoff quality/quantity. A nonstructural best management practice is a regulation or guideline that is enforced so that the control of water quality/quantity can be improved. An example of this might be a local ordinance or regulation for the disposal of used motor oil. Best management practices are needed as a result of changes in the watershed hydrology due to urbanization (see Figure 1).

As seen in Figure 1 a), "Water Balance", urbanization reduces vegetation and increases impervious area, which in turn reduces transpiration, interflow, and baseflow, but increases surface runoff. In Figure 1 b), "Streamflow", urbanization increases peak discharge rates but decreases baseflow rates. In Figure 1 c), "Response of Stream Geometry", urbanization raises the floodplain limit but decreases the summer low flow level. Best management practices are used to counter the effects of urbanization on the hydrology of a watershed.

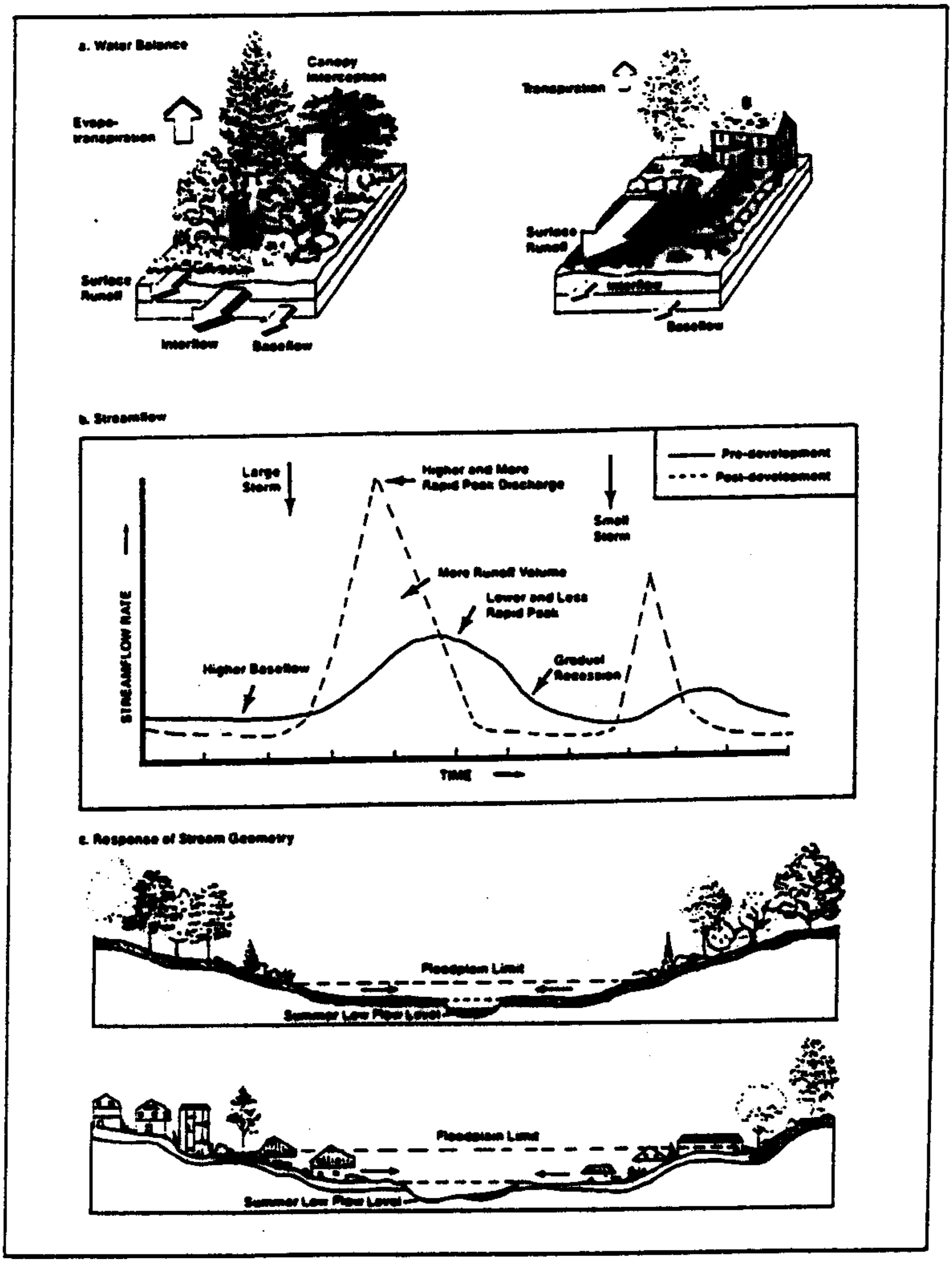

Figure 1. Changes in Watershed Hydrology due to Urbanization (Source: Schueler 1987)

Structural Best Management Practices

Structural best management practices can be broken down into seven important categories:

- Detention Ponds
- Retention Ponds
- Infiltration Basins
- Infiltration Trenches
- Porous Pavement
- Water Quality Inlets (oil and grease removal)
- Vegetative Systems.

A discussion of the management practice, a summary of the associated efficiencies, if available, as well as highlights of the advantages and disadvantages of each category follow.

Detention Ponds

Detention ponds act as a permanent storm water management structure, with the primary purpose of temporarily storing storm water runoff and releasing it at a controlled rate (SCLRCC 1992). A detention pond's storage pool is usually dry before a storm event (see Figure 2).

If detention ponds are designed such that the storage time is extended, then a high level of particulate removal can be achieved. This is important because many contaminants are removed by settling. The detention pond with extended storage time (for short, extended detention pond) does not remove soluble pollutants, such as ammonia, and orthophosphate. The information defining approximate percent removed (see Table 1) is available from the Occoquan Watershed Monitoring Laboratory (OWML 1983). These data are based on both field and laboratory settling column observations. The settling data are an average of seven column tests, which matched well with field measurements. The pollutants studied were: total suspended sediments (TSS), lead (Pb), zinc (Zn), chemical oxygen demand (COD), total phosphorous (TP), and total nitrogen (TN). Unfortunately, extended detention ponds were not evaluated in the NURP (EPA, 1983). It was therefore concluded, probably incorrectly, that detention ponds were ineffective at improving water quality. It is due to the fact that modified detention ponds with extended detention times were not evaluated.

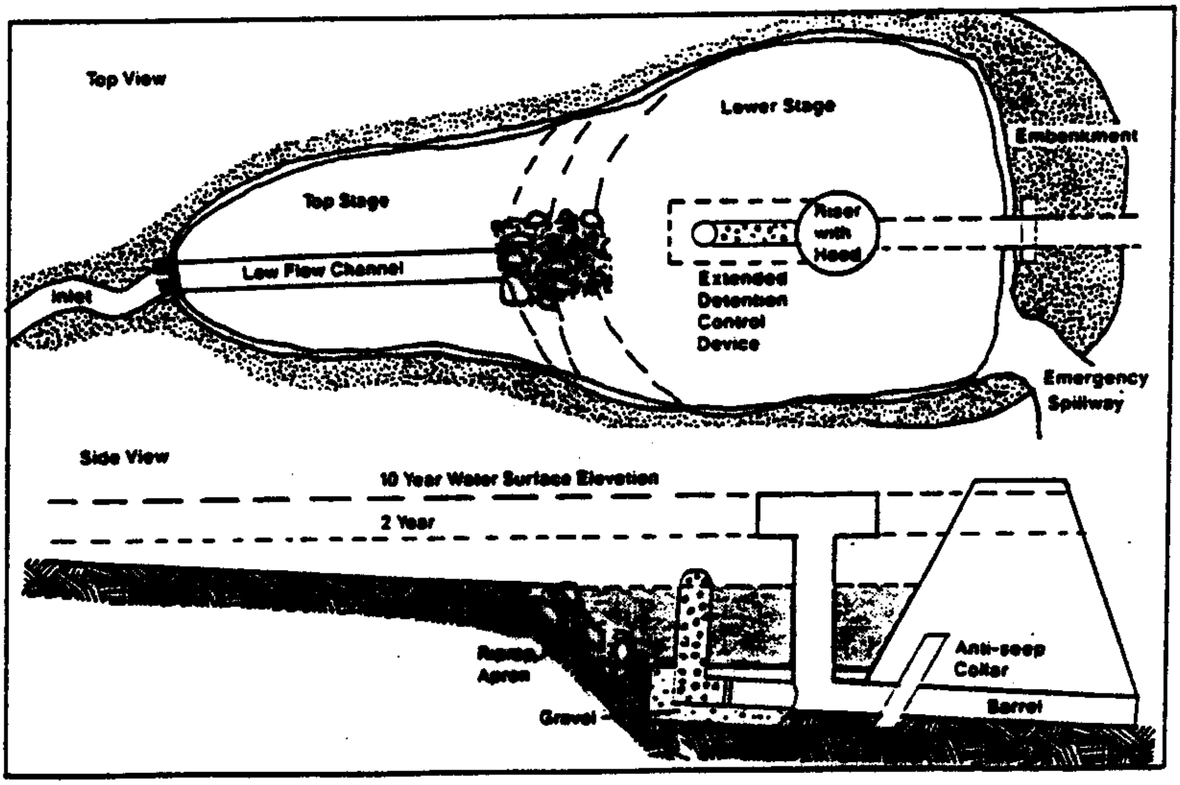

Figure 2. Schematic of Dry Extended Detention Pond
(Source: Schueler 1987)

Table I

Pollutant Removal With Respect to Detention Time

Pollutants	% Removed 12 hours	% Removed 24 hours	% Removed 48 hours
TSS	66	75	92
Pb	74	81	85
Zn	44	43	48
COD	34	40	52
TP	44	46	52
TN	24	31	33

Schueler (1987) suggests that a minimum detention time of twenty-four hours is needed for efficient removal of suspended solids and particulate bound contaminates. Grizzard (1986) also suggests a target detention of twenty-four hours, for the average storage time of all storms occurring in any given year, be used for design. To meet this requirement, a design value of approximately forty hours is suggested for the maximum detention time, for the maximum designed detention volume (Grizzard 1986). It should also be noted that through the detaining of all storms, increased pollutant removal will occur. The detaining of small storms, (which would have typically passed through the pond) will have a dramatic effect on reducing the pollutant loading entering adjacent water bodies, thereby, improving overall water quality.

Site suitability is very important in the selection of any best management practice. In this regard, (extended) detention ponds should not be recommended as a best management practice for development sites of less than ten acres (Schueler 1987). Some engineers indicate that development sites of twenty acres or more are more suitable for using (extended) detention ponds as a best management practice.

Other factors that should be considered are soil classification, water table, and depth to bedrock. Some soils are prone to erosion and scour. These soils should be avoided in designing of detention ponds. A detention pond is designed to be dry prior to storm events. If high groundwater tables exist then the pond may not ever be dry. Wet conditions tend to increase the possibility of causing odors and mosquito breeding grounds. The depth to the bedrock is important because of the high cost of rock excavation.

The advantages of using (extended) detention ponds as best management practices are that water quantity can be stored and released at controlled rates and that water quality can be enhanced. A disadvantage of using a detention pond is that the controlled release rates, if improperly planned or designed, can cause downstream flooding during frequently occurring storm events. This is due to the fact that upstream, less developed areas, have longer times of concentration and therefore the time to the peak flow rate is offset (American Society of Civil Engineers (ASCE) Water Forum 1992 - McEnroe (1992), Traver (1992), George (1992)). Another disadvantage is that extended detention ponds, due to improper or lack of maintenance, can become a nuisance. The nuisance can involve unpleasant odors, mosquito breeding, or in general, a diminished aesthetic appeal.

Retention Ponds

Retention ponds act as a permanent storm water management structure, with the primary purpose to permanently store a given volume of storm water runoff (SC LRCC 1992). A retention pond has a permanent storage pool that is always wet, even when a storm event is not occurring and a temporary storage pool for storm water (see Figure 3). When a storm event occurs, storm water runoff will temporarily be stored and then released at a controlled rate.

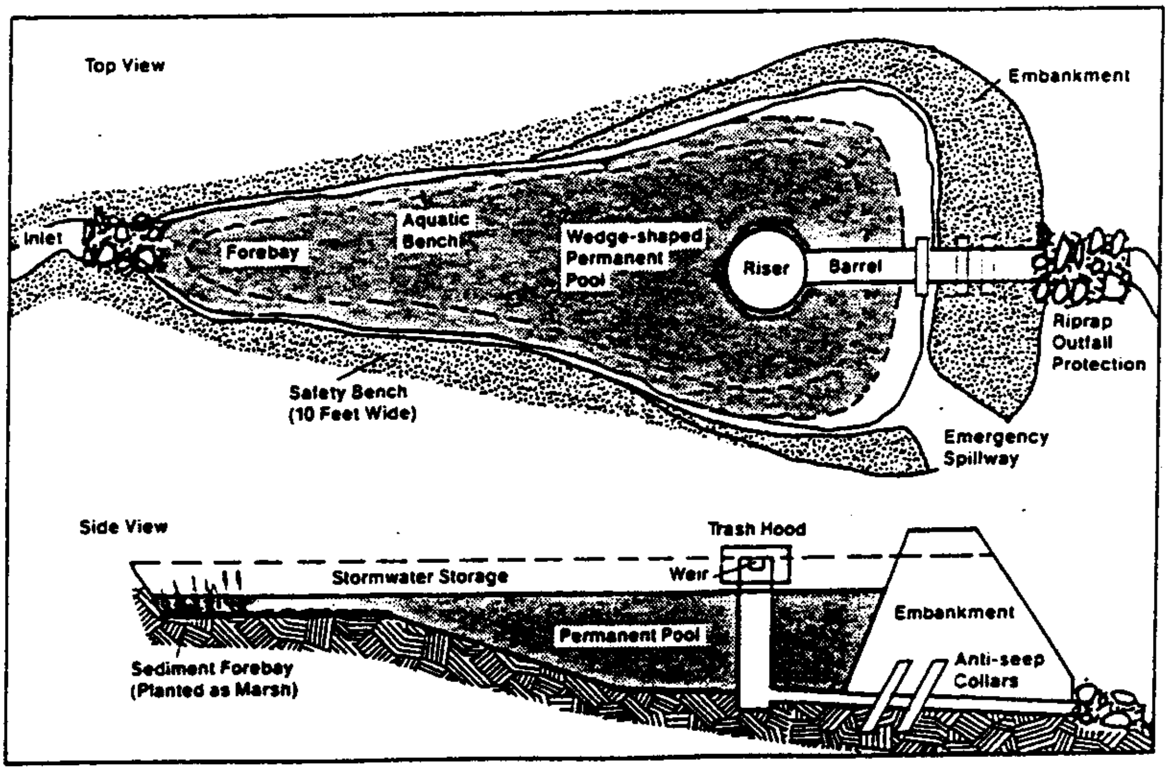

Figure 3. Schematic of Retention Pond
(Source: Schueler 1987)

An optimal retention pond design performs as a multipurpose best management practice which controls storm water runoff discharges, improves water quality, and provides habitats for both plants and animals. Retention ponds can attain a high removal rate of sediment, BOD, organic nutrients, and trace metals. With the much longer detention times associated with retention ponds, algae and aquatic plants thrive and remove ammonia, nitrate, and orthophosphate. These soluble nutrients are converted to biomass and eventually settle out. Detention ponds tend to have shorter storage times, thus less algae and aquatic plants are available to remove soluble nutrients (Schueler 1987).

The basic theory behind the design and development of retention ponds is that storm water runoff enters the pond and is stored. The previously stored runoff water, which was "treated" through, settling, adsorption, or biological uptake, is then forced out of the basin by the incoming runoff waters. This is not always the case. If the flow distance between the inlet(s) and outlet(s) are not sufficiently great, then short circuiting of the pond can occur and treatment of the storm water runoff will be ineffective. This problem can be eliminated if pond designs are "wedge" shaped (Schueler 1987). This is also true for detention ponds

NURP recorded that predicted long term efficiencies of retention ponds ranged from excellent to very poor (USEPA 1983). NURP indicates if the retention ponds were properly designed (sized), that total suspended solids and lead removals were achieved in excess of 90%. Pollutants with high soluble fractions showed lower removal rates, on the order of 65% for total phosphorous (TP), and approximately 50% for BOD, COD, total Kjeldahl nitrogen (TKN), copper, and zinc.

Surveys show that residents prefer retention ponds over detention ponds by a 3 to 1 margin (Adams 1983). In other surveys, residents found retention ponds improved the aesthetics of the community, which thereby enhanced property values (Baxter 1985).

The biggest disadvantage associated with retention ponds is the liability associated with the safety of the pond. The pond could be considered as an "attractive nuisance." An attractive nuisance is defined as anything that could attract a child; a lake, pond, pool, play area, etc. The cause of harm to the child need not be the attractive nuisance (Chapman 1992). Some municipalities require that retention ponds be fenced to protect children from drowning. This however reduces some of the aesthetic value of the pond. Schueler suggest's some guidelines to minimize the risk of accidental drowning (Schueler 1987):

- fence off large diameter outlets
- avoid sharp drop offs near shorelines
- install under water safety bench
- pond depths should be kept relatively shallow.

Other disadvantages are similar to those associated with detention ponds, in that flooding could occur downstream even at frequently occurring design storms, and the lack of funds for proper maintenance. A considerable disadvantage, is that sediment removal from retention ponds is very expensive. The sediment must be dredged, then allowed to dewater.

Disadvantages also include the raising of downstream temperature and the depletion of dissolved oxygen (DO). Retention ponds' large surface area and storage volume facilitate faster heating which supports faster algae growth and decay which depletes dissolved oxygen. During the warmer summer months, one study determined that downstream receiving water temperature had increased as much as 10 to 11°F (5.6 to 6.1°C) because of retention ponds (Galli 1986). This temperature rise can cause severe stress or kill temperature sensitive aquatic life (i.e. trout). To counteract the effect of raising the water temperature, outfalls can be constructed so that the cooler bottom water is discharged. In coastal regions, topography are very flat and bottom water discharges will not always be feasible. Another means of cooling water temperature is to landscape the basin (discussed later in "Vegetation Systems - Basin Landscaping") with trees and shrubs to provide shade to the pond. Shading around the pond, however, will reduce algal growth which in turn could reduce nutrient removal.

Dissolved oxygen can be periodically depleted during the summer months if eutrophication occurs. The end result is that algae take up all the dissolved oxygen and anoxic waters are discharged. Downstream aquatic life will be drastically altered until atmospheric aeration increases the dissolved oxygen to normal levels (Galli 1986 and Free and Mulamootil 1983). A suggestion to alleviate this problem is to add a fountain or aerator system to the pond (Schueler 1987).

Infiltration Basins

Infiltration basins capture and store runoff, and then allows the storm water to infiltrate into the ground or to be evaporated. Infiltration basins, like detention ponds, are typically dry before a storm event. However, infiltration basins have a much longer holding time than detention ponds. This is due to the fact that infiltration basins remove storm water runoff by exfiltration and detention ponds release the storm water runoff with a controlled outlet structure. Exfiltration is the downward movement of storm water runoff through the soil profile (Schueler 1987). Infiltration basins and retention ponds are similarly effective at recharging groundwater.

Infiltration basins can be an extremely efficient best management practice to improve water quality but require regular maintenance. Regular maintenance for any infiltration best management practice is required but is an absolute must for infiltration basins because of high failure rates. Similar to an infiltration trench, an infiltration basin should have a vegetative filter strip (see "Vegetative Systems - Filter Strips") that remove coarse sediments, trash, and other debris. Infiltration basins are typically designed to contain the entire runoff of the 2 year design storm (see Figure 4). The drainage area, when an infiltration basin is used as a best management practice, should typically be no greater than about 50 acres (Schueler 1987). The soils should again have moderate to high permeability, and the bedrock and water table should be located at a minimum of 2 to 4 feet from the bottom of the infiltration basin.

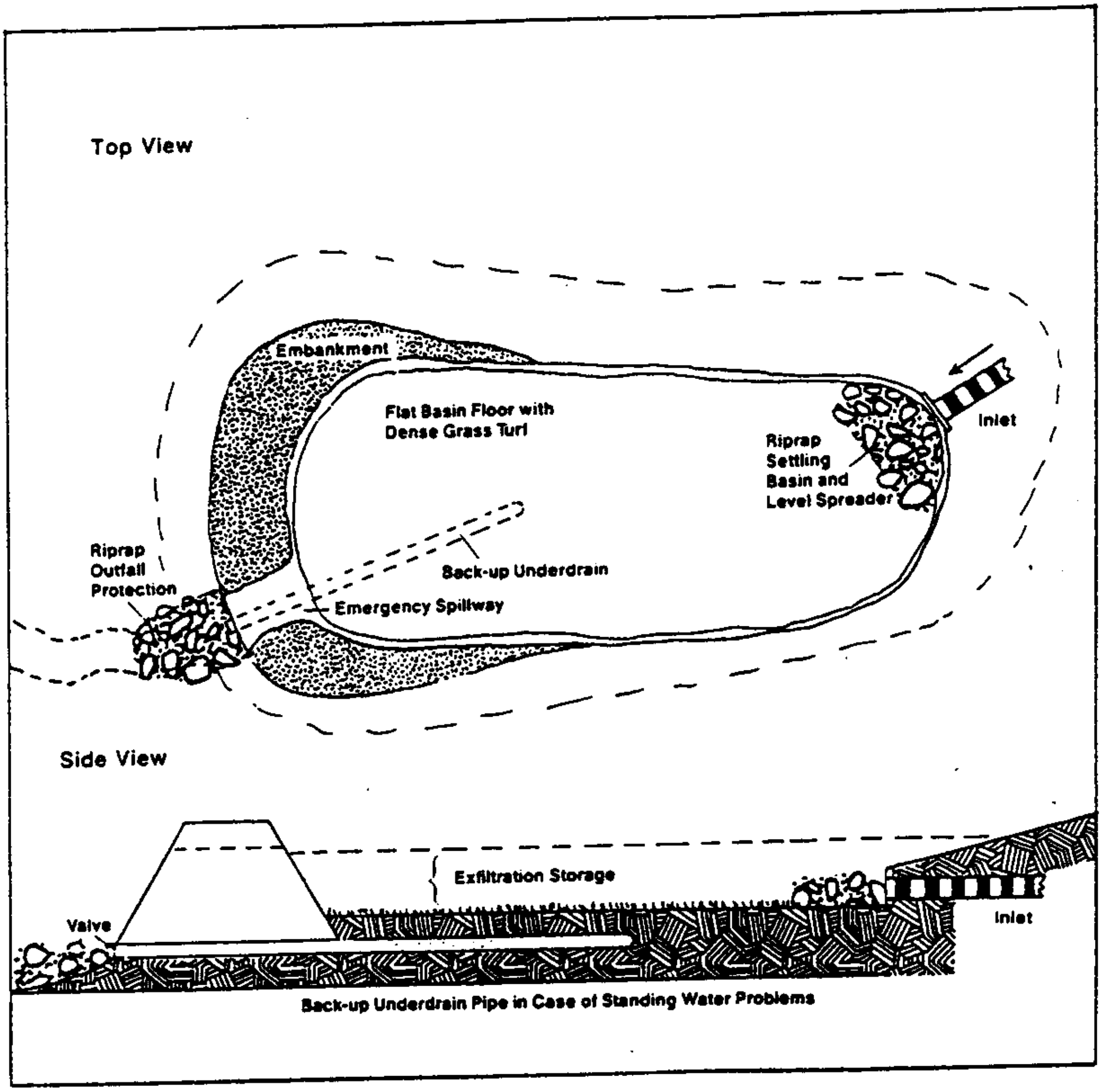

Figure 4. Schematic of Infiltration Basin
(Source: Schueler 1987)

Current design practice dictates that an emergency spillway and backup under-drain be included in the design of the infiltration basin. The emergency spillway allows runoff volumes generated greater than the two year design storm to pass on through the basin. The backup under-drain allows the basin to be drained if infiltration capacity of the basin fails (i.e. runoff is taking to long to exfiltrate). Common design practices also dictate that a minimum infiltration time of six hours is needed but the infiltration time should be no greater than seventy-two hours. This is so that proper pollutant removal can be achieved and so that the basin will not become a community nuisance (i.e. odors, mosquitos, etc.).

Another common design practice is to have the bottom slope of the basin as close as possible to zero. This maximizes the surface area for infiltration to occur and does not promote premature clogging in a lower lying area. Flow at the inlet should also be controlled by energy dissipators so that erosive velocities are avoided, which could lead to scour and/or re-suspension of pollutants (Schueler 1987).

The establishment of water tolerant turf grass is critical to the success of the infiltration basin. The turf grass maintains infiltration capacity, keeps accumulated pollutants from being re-suspended, and adsorbs soluble pollutants. The removal mechanisms used by infiltration basins are sorption, trapping, straining, precipitation, and bacterial degradation or transformation (Schueler 1987).

NURP did not report efficiencies for infiltration basins but indicated that recharge management practices were capable of providing very effective pollutant removal (USEPA 1983). Schueler (1987) estimates the long term removal rate (for the two year runoff volume) to be 99% for sediment, 65 to 75% for total phosphorous, 60 to 70% for total nitrogen, 95 to 99% trace metals, 90% for BOD, and 98% for bacteria. These estimates are based on field testing of rapid infiltration land treatment systems conducted by NVPDC (1979) and USEPA (1977).

Infiltration basins have several different variations of the basic design.

- Full Infiltration Basin Design (Fig. 3)
- Combined Infiltration/Detention Basin Design (Fig. 4)
- Side-by-Side Basin Design (Fig. 5)
- Off-Line Infiltration Basin Design (Fig. 6)

Advantages of infiltration basins are: efficient removal of pollutants, sedimentation basins in the construction phase (must then be regraded), recharge groundwater, and protection of downstream aquatic life (by maintaining pre-development baseflows even during the low flows associated with summer months). Disadvantages are the relatively high failure rate, the risk of groundwater contamination, and the aesthetically displeasing attributes a failed basin can have on a community. High failure rates are from inadequate designs, improper maintenance, or site conditions proving to be unsuitable for infiltration.

Figure 5. Full Infiltration Basin Design
(Source: Schueler 1987)

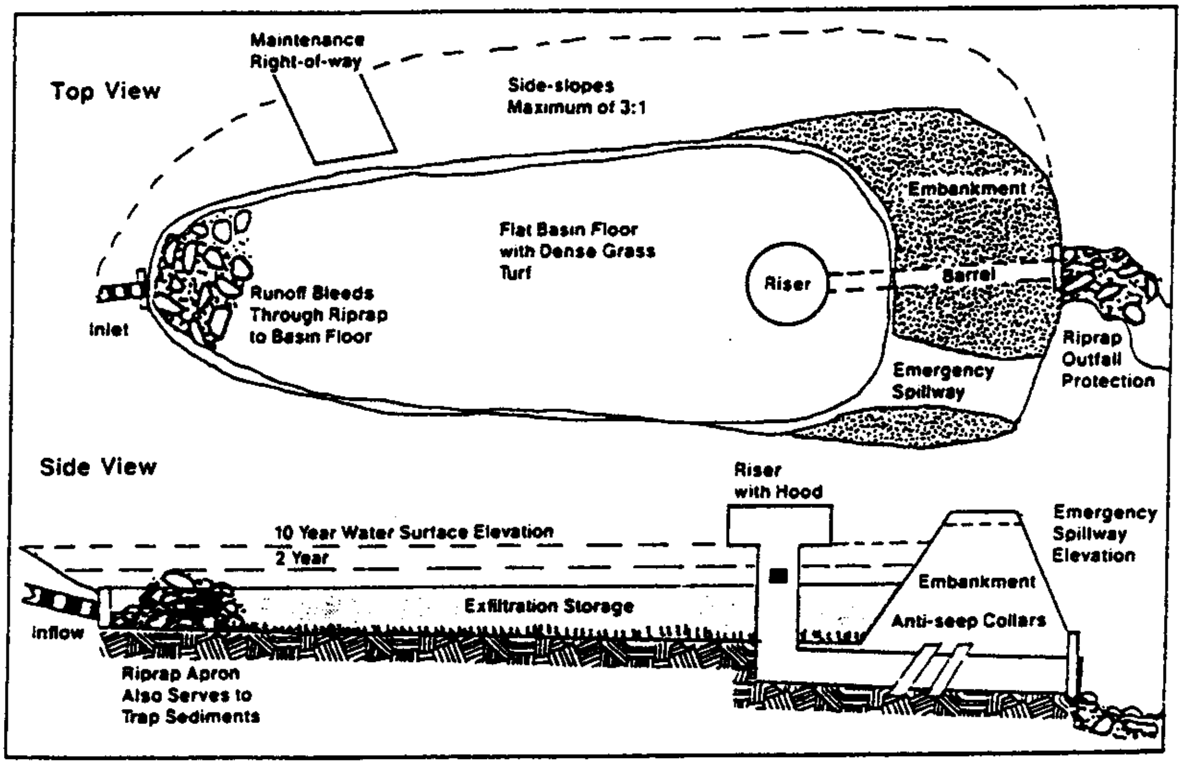

Figure 6. Schematic of Combined Infiltration/Detention Basin Design
(Source: Schueler 1987)

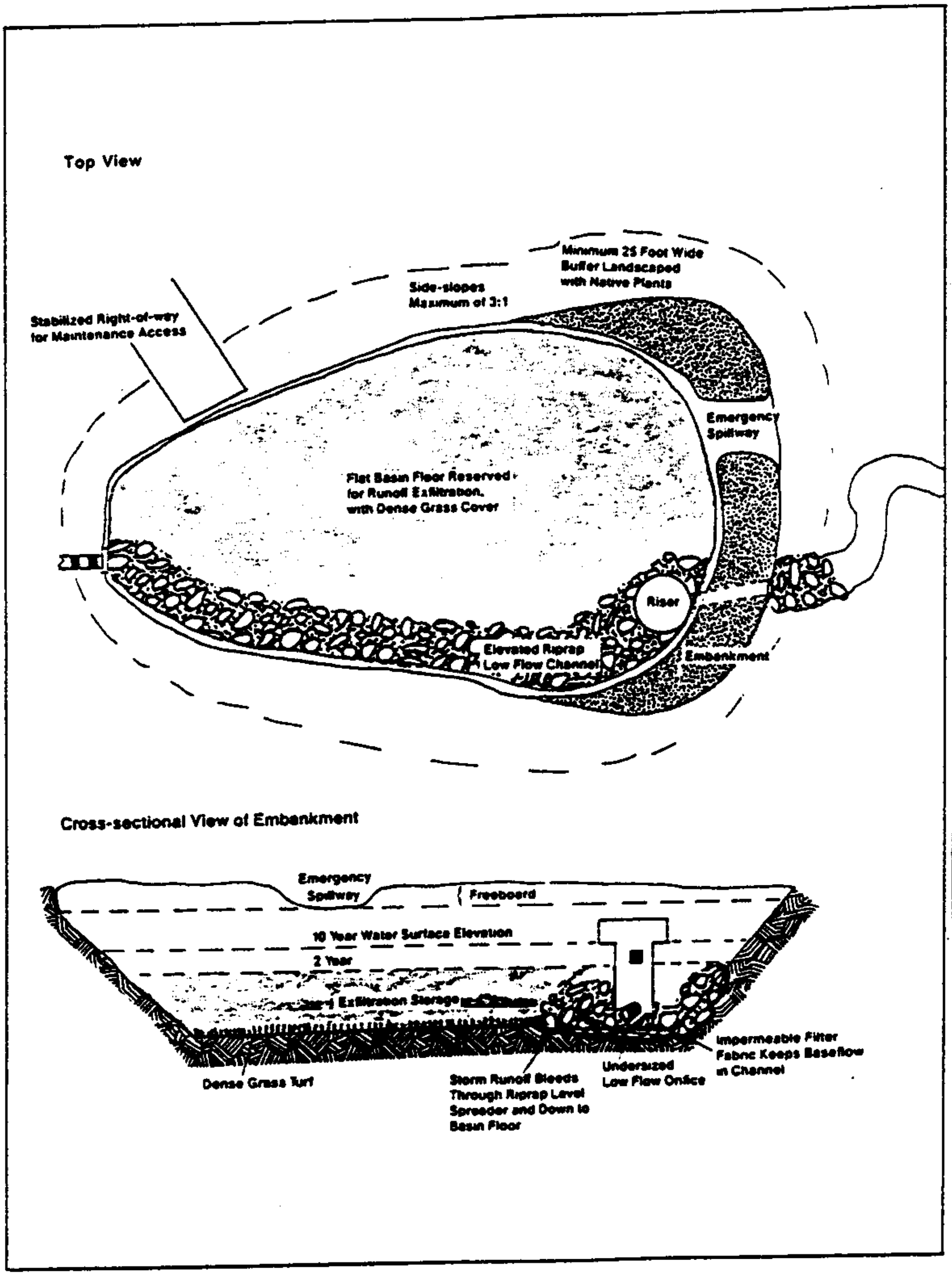

Figure 8. Schematic of Side-by-Side Infiltration Basin Design (Source: Schueler)

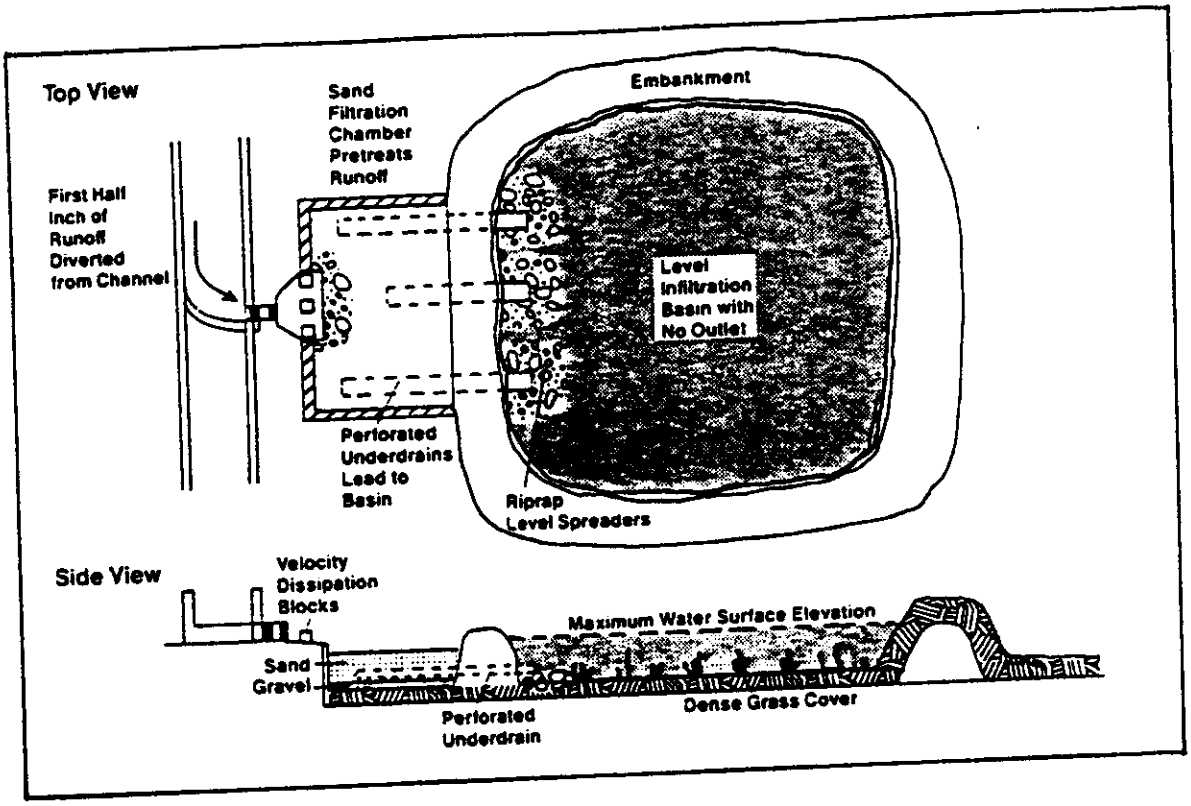

Figure 8. Schematic of Off-Line Infiltration Basin Design (Source: Schueler 1987)

Infiltration Trenches

Infiltration trenches are an effective best management practice that can remove both particulate and soluble pollutants. Infiltration trenches are placed strategically so that storm water runoff will flow across and be trapped. The water is then allowed to infiltrate into the ground. The trenches are excavated and refilled with 1.5 to 2.5 inch stone (see Figure 9). A vegetative filter strip (see "Vegetative Systems - Filter Strips") must also be constructed just upstream of the trench to capture heavier sediments, trash, and other debris.

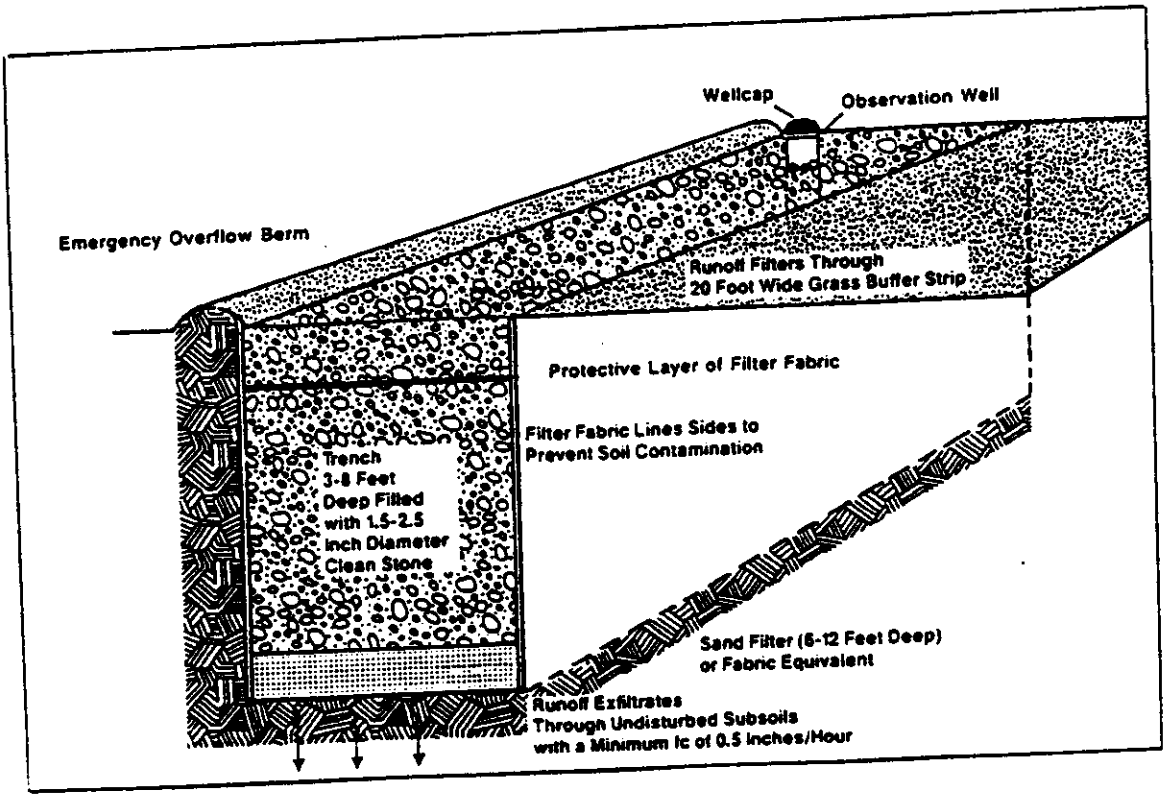

Figure 7. Schematic of Infiltration Trench (Source: Schueler 1987)

For infiltration trenches to be effective, base soils should have moderate to high permeability. Another site requirement is that the bedrock and groundwater tables should be a minimum of 2 to 4 feet from the bottom of the trench. Also, infiltration trenches are not recommended as the sole best management practice for development sites greater than 5 to 10 acres (Schueler 1987).

Pollutant removal mechanisms that are employed by infiltration trenches are through sorption, trapping, precipitation, straining, and bacterial degradation or transformation. The most efficient removal of pollutants occurs when it takes at least 6 hours, but no more than 72 hours for the storm water runoff to drain (or exfiltrate) from the infiltration trench (Schueler 1987).

Good design practice suggest that a monitoring well, a 4 to 6 inch diameter PVC pipe with a removable cap, be installed in the trench (Schueler 1987). The monitoring well allows an inspector to determine if the infiltration trench is working properly. A maintenance program that includes routine inspections, should also be included as part of the design of an infiltration trench. A routine maintenance and inspection schedule is necessary to prevent premature clogging of the trench.

There are two basic designs applications for infiltration trenches, surface and subsurface trenches. Some variations to the basic design are listed below.

Surface Trenches
- Median Strip Design (Fig. 10)
- Parking Lot Perimeter Design (Fig. 11)
- Swale Design (Fig. 12)

Subsurface Trenches
- Oversized Pipe Trench Design (Fig. 13)
- Underground Trench with Oil/Grit Inlet Design (Fig. 14)
- Under-the-Swale Design (Fig. 15)
- Dry Well Design (Fig. 16)
- Off-Line Trench System Design (Fig. 17)

NURP data did not report efficiencies for infiltration trenches but indicated that recharge management practices were capable of providing very effective pollutant removal (EPA 1983). Schueler estimates the long term removal rate to be 99% for sediment, 65 to 75% for total phosphorous, 60 to 70% for total nitrogen, 95 to 99% trace metals, 90% for BOD, and 98% for bacteria (Schueler 1987). The reader should be aware that Schueler (1987) based these removal rates on local modeling studies (NVPDC 1979) and field studies of the first flush phenomena by Griffin, et al. (1980).

The advantage of using infiltration trenches as best management practices are that they can be placed easily on strips of unutilized spaces of development, reduce volume of runoff directly leaving the development site, and can act to recharge site groundwater. The disadvantages of using infiltration trenches is that with out preventative maintenance, and proper education of maintenance personal, the trench can become quickly clogged and ineffective. The risk of groundwater contamination can be a possibility but no more so than other infiltration practices (Schueler 1987).

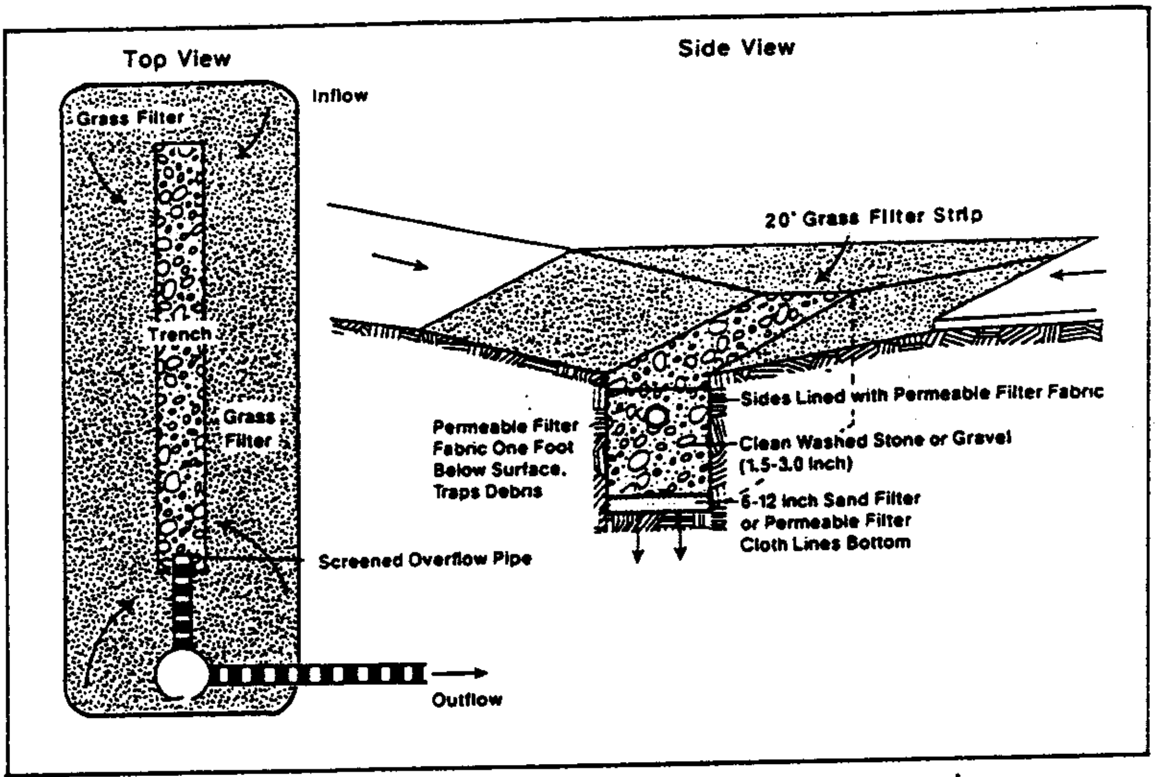

Figure 10. Schematic of Median Strip Trench Design (Source: Schueler 1987)

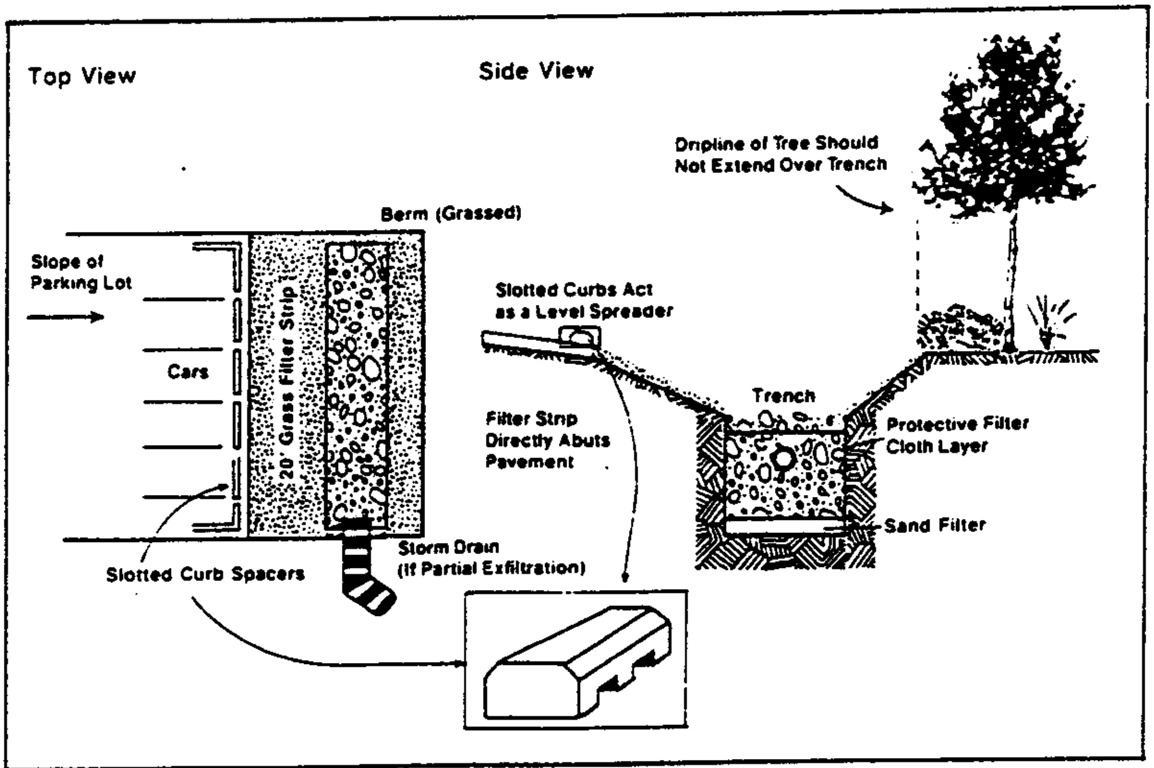

Figure 11. Schematic of Parking Lot Perimeter Trench Design (Source: Schueler 1987)

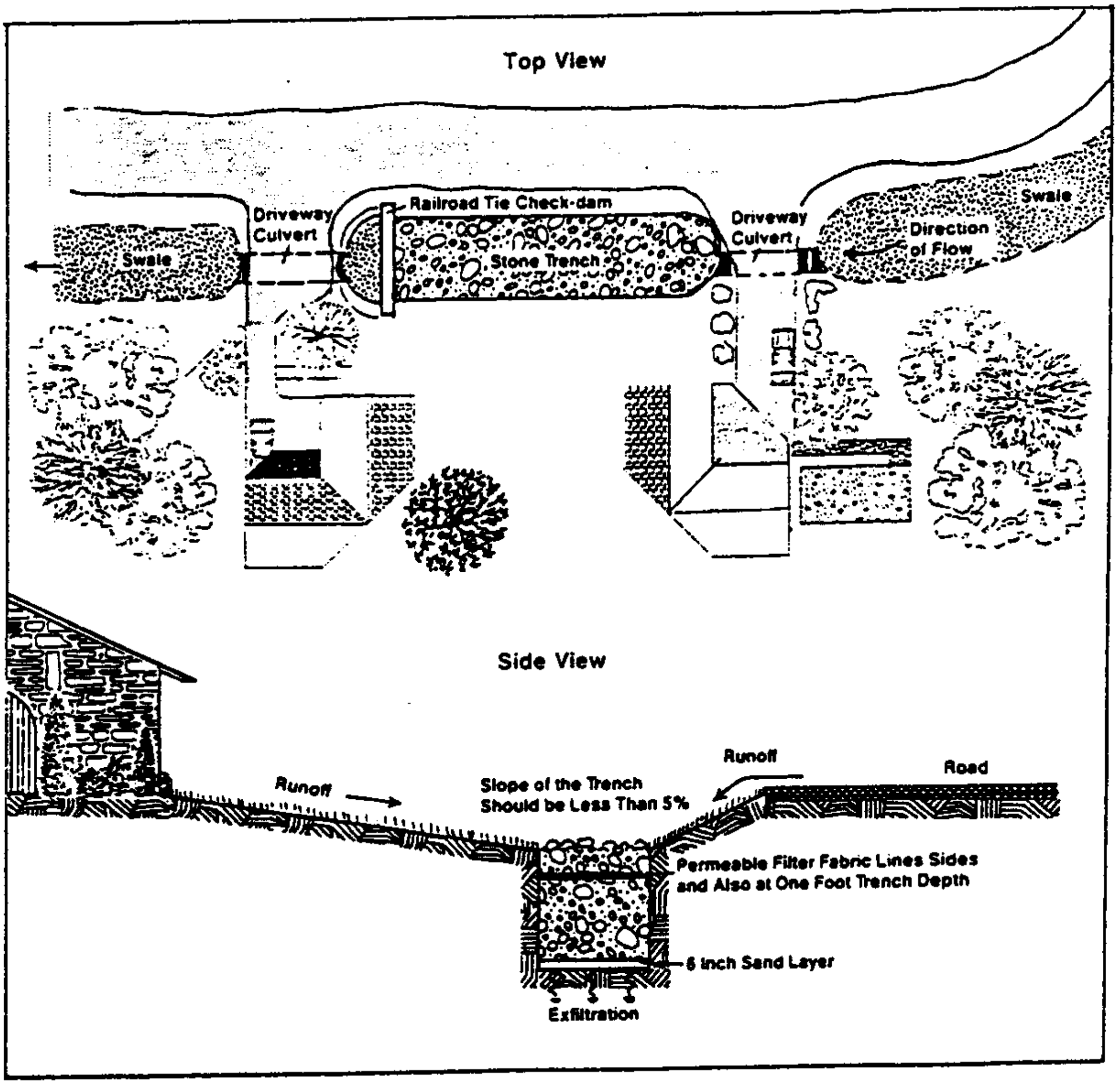

Figure 12. Schematic of Swale/Trench Design
(Source: Schueler 1987)

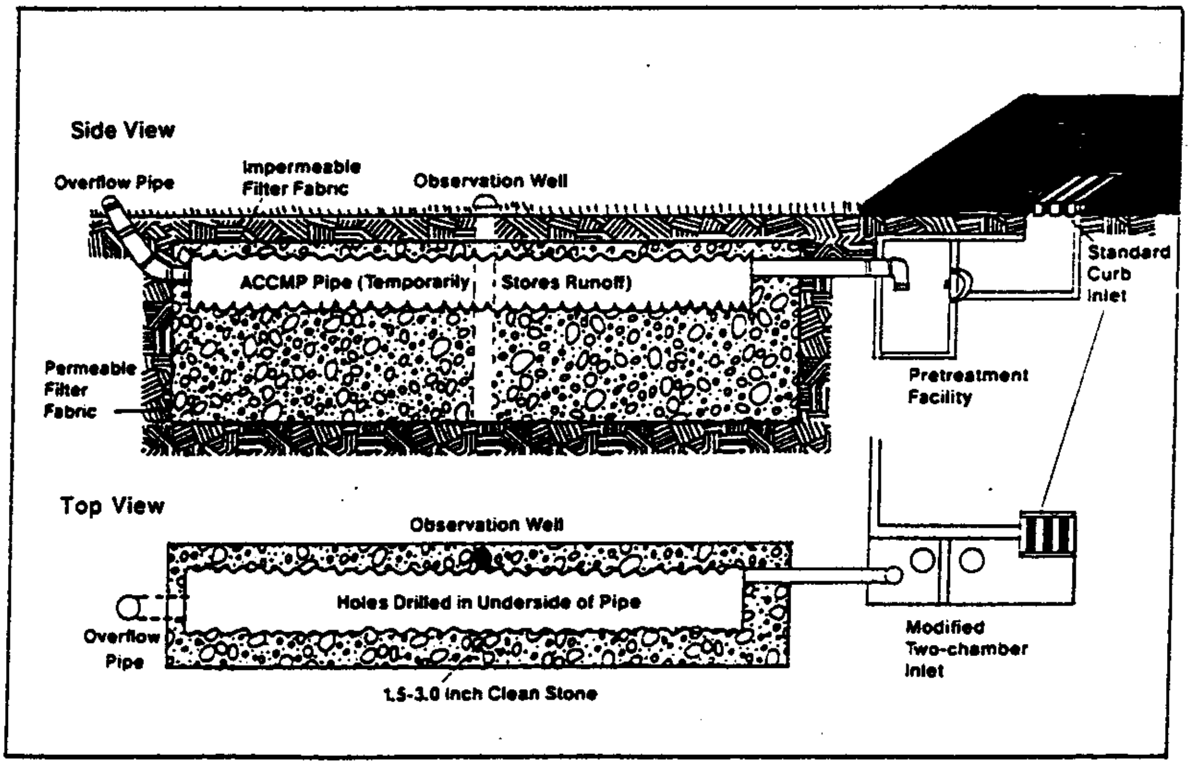

Figure 13. Schematic of Oversized Pipe Trench Design (Source: Schueler 1987)

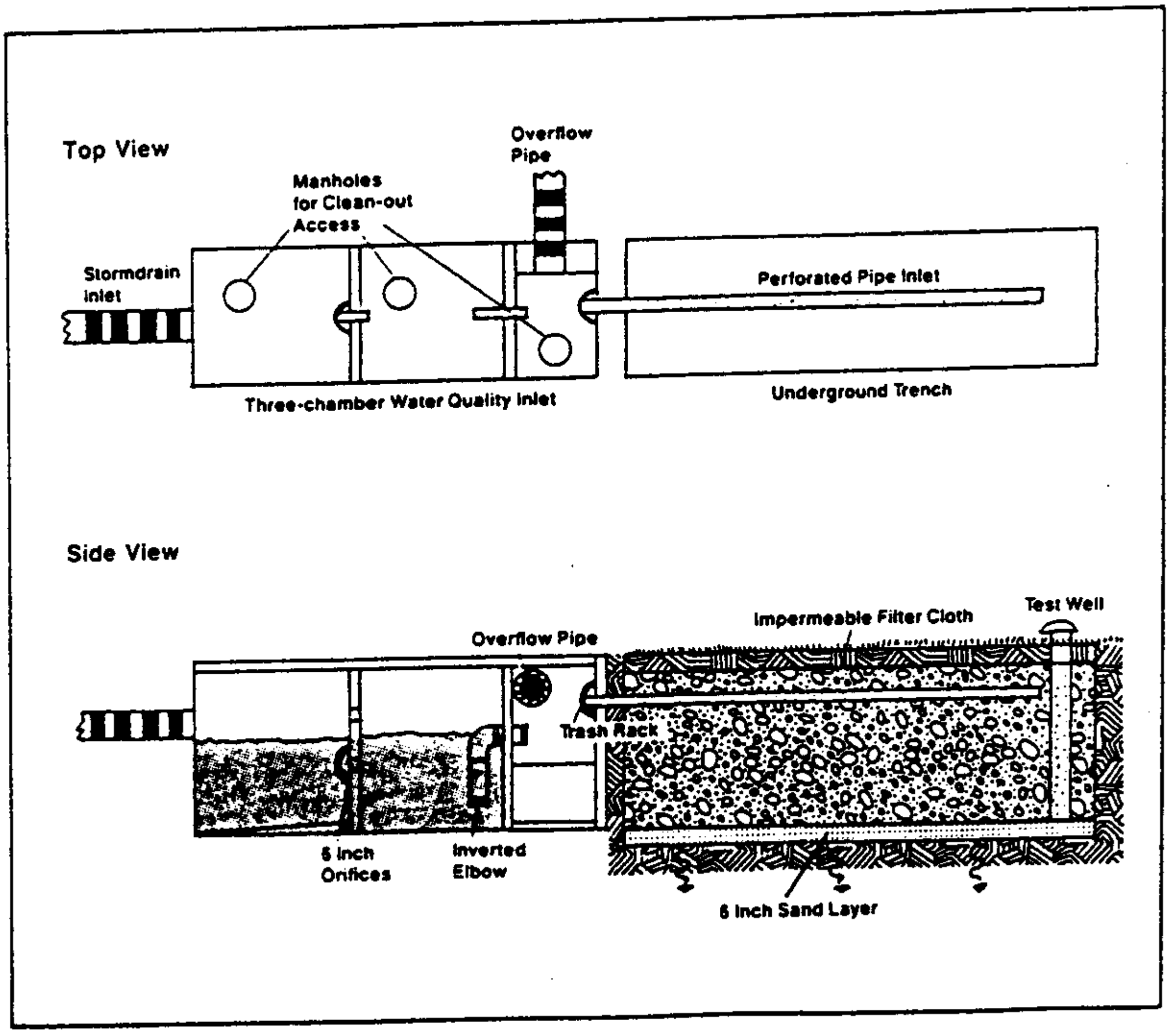

Figure 14. Schematic of Underground Trench with Oil/Grit Chamber
(Source: Schueler 1987)

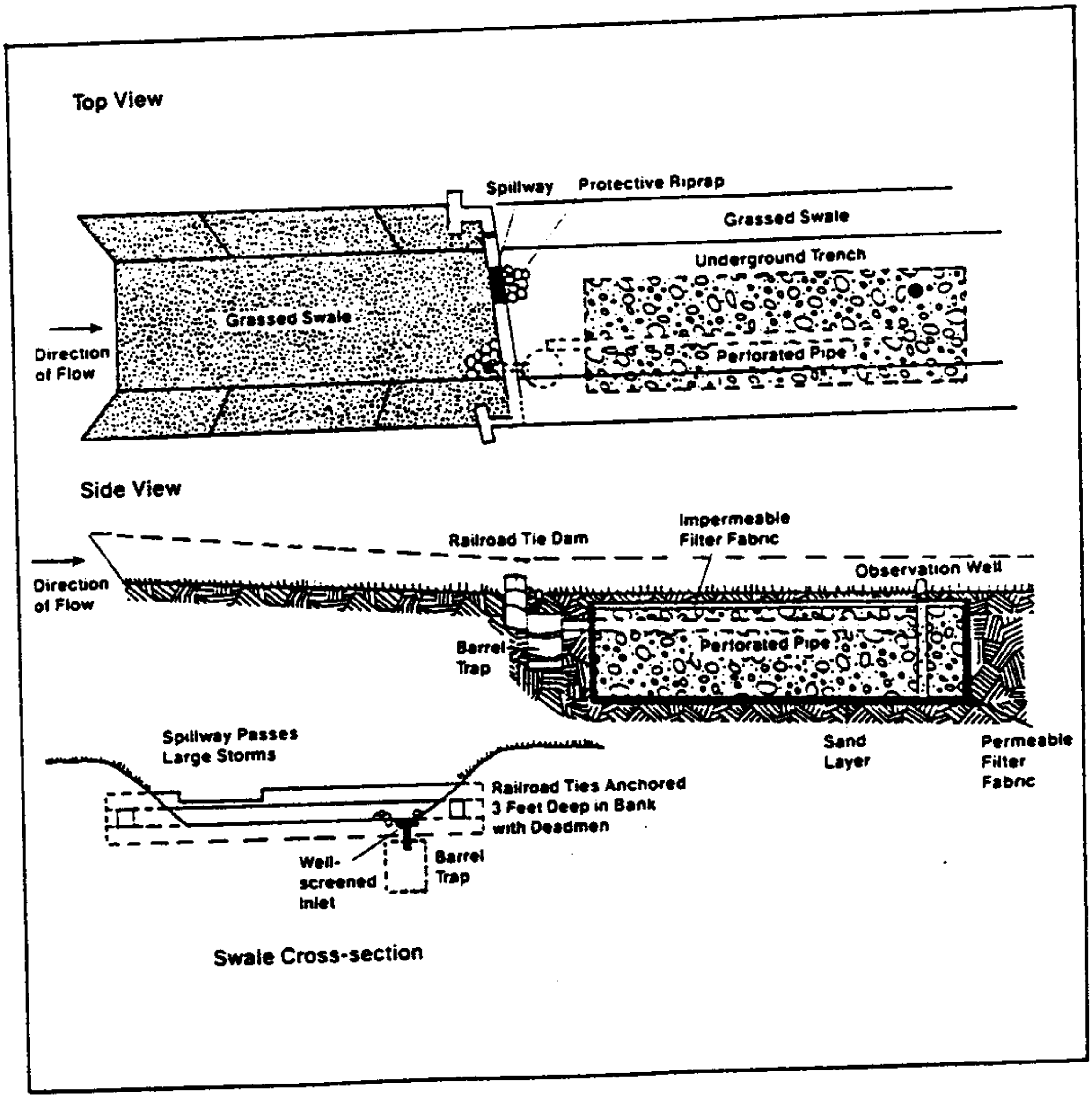

Figure 15. Schematic of Under-the-Swale Trench Design (Source: Schueler 1987)

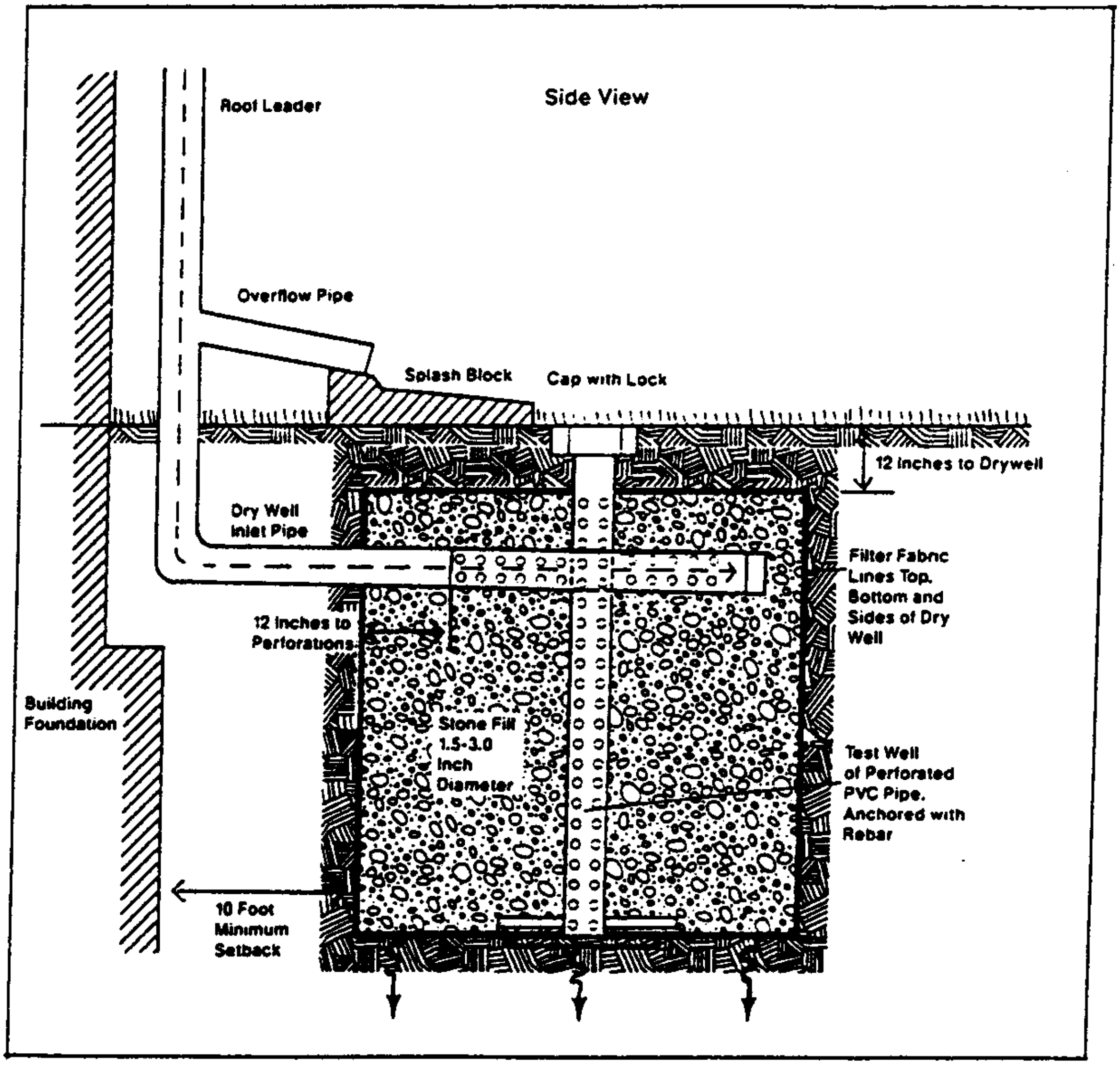

Figure 16. Schematic of Dry Well Design
(Source: Schueler 1987)

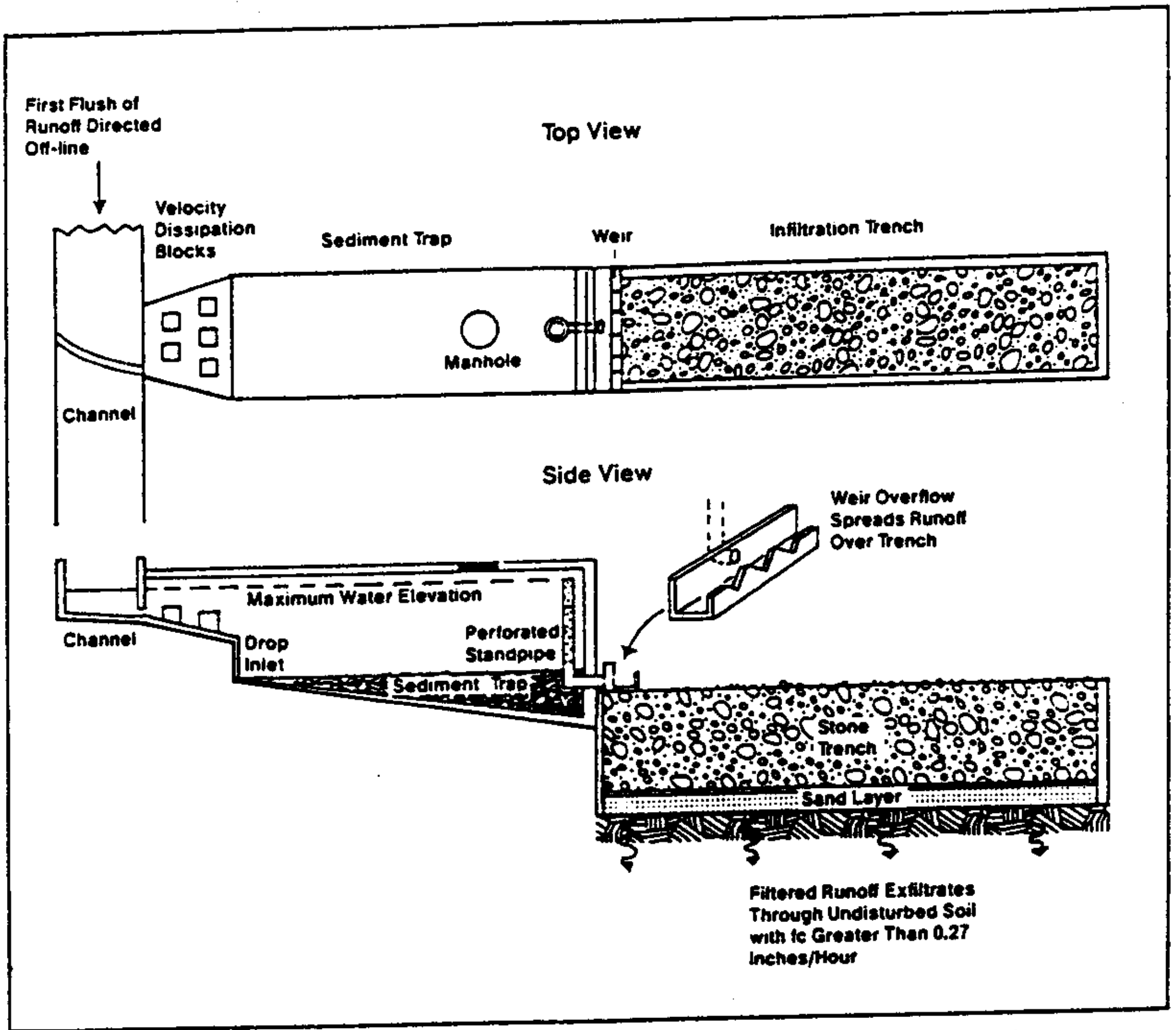

Figure 17. Schematic of Off-line Trench System Design (Source: Schueler 1987)

Porous Pavement

Porous Pavement has the ability to allow storm water runoff to infiltrate rapidly through its pores. Porous pavement can typically be used in parking areas, however, it is not recommended for highway or street paving. Porous pavements have a similar cross-section as regular pavements. The top layer is porous pavement asphalt, then a filter layer, a stone (aggregate) reservoir, another filter layer, and a filter fabric that covers the natural soil (see Figure 18). In porous pavement applications, the aggregate layer is much deeper to allow for the storage of storm water runoff until it can infiltrate into the ground (Schueler 1987).

Porous pavements are good best management practices for low volume traffic parking lots, with surface area between 0.25 and 10.0 acres. The use of porous pavement has very strict site limitations for the practice to be effective (see Figure 19). The soils must have moderate to high permeability. The slope of the site topography must be very mild (less than 5%). The water table and bedrock should be 4 to 6 feet below the porous pavement cross-section. Porous pavements can remove both soluble and particulate pollutants. Schueler (1987) indicates that porous pavements are unique in that they can almost completely reproduce the pre-development hydrologic regimen at a site, within a reasonable degree.

Porous pavements are not effective at removing coarse particulate pollutants, in fact, if they are allowed to reach the paved surface, failure could occur due to clogging of asphalt or filter pores. The use of porous pavement is primarily designed to remove pollutants falling onto the surface of the pavement from the atmosphere. The removal mechanisms that porous pavements use are sorption, trapping, precipitation, straining, and bacterial degradation or transformation (Schueler 1987). Similar to the other infiltration practices, a minimum of 6 hours and no greater than 72 hours of exfiltration time is desired for proper pollutant removal.

NURP did not report efficiencies for porous pavements but indicated that recharge management practices were capable of providing very effective pollutant removal (USEPA 1983). Schueler (1987) provides data for two test sites, but the efficiencies were not compatible. It was speculated that differences in efficiencies existed because of varying design requirements.

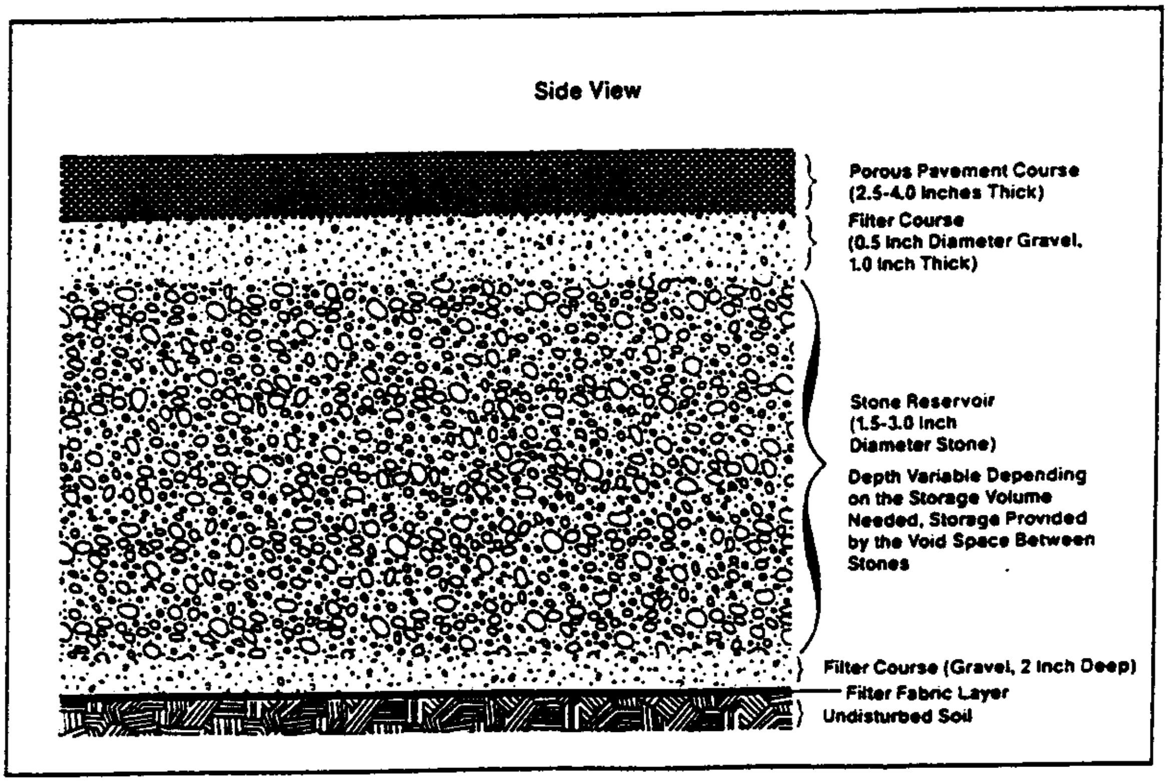

Figure 18. Schematic of Typical Porous Pavement Section (Source: Schueler 1987)

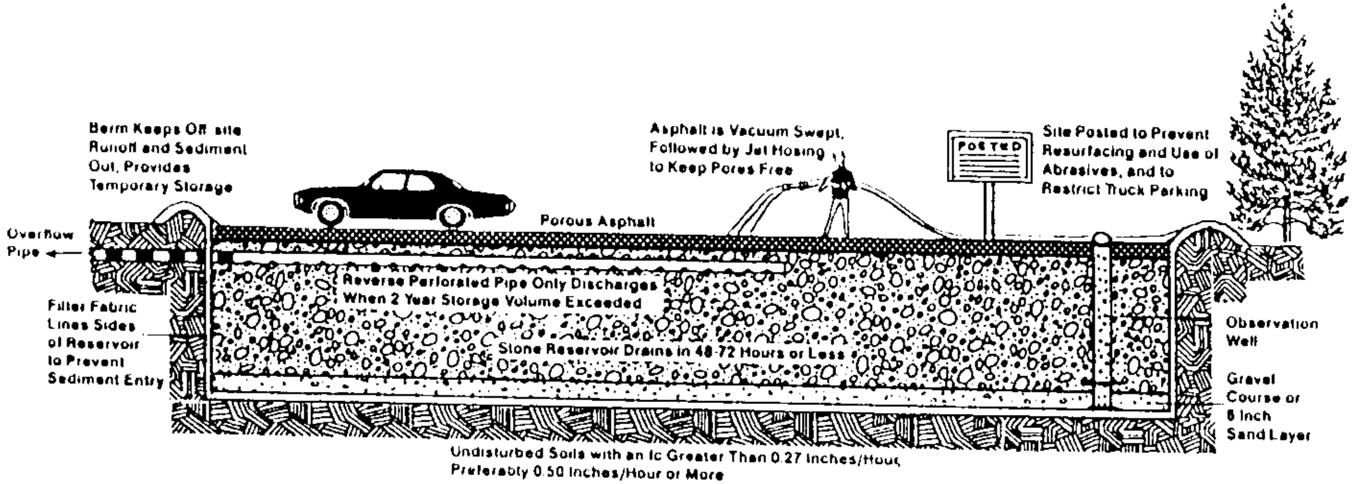

Figure 17. Design Schematic for Porous Pavement
(Source: Schueler 1987)

A detailed construction specification and maintenance guideline for porous pavement construction is provided by Schueler (1987), in Chapter 7.

The advantages of using porous pavement as a best management practice are that it reduces land consumption, amount of storm water conveyance systems required, and provides a safer driving surface that reduces the risk of hydroplaning (Schueler 1987). Land consumption is reduced because porous pavements have the dual purpose of acting as a parking area and a best management practice. This in turn reduces the amount of land needed for other best management practices. The conveyance systems are reduced because curb and gutter systems are not needed. A curb and gutter system acts to concentrate flows which is not desirable for porous pavements. The driving surface of porous pavements is rougher than normal parking lot pavements, thereby lowering the risk of hydroplaning.

The major disadvantage is that if porous pavement does become clogged, the cost of rehabilitating the pavement system is very costly. The careful design and construction of porous pavement is very important. A high degree of workmanship for installing porous pavement is necessary and is unlikely available through low bid construction site work. High intensity storms may not be infiltrated by the porous pavements quickly enough and temporary flooding could occur. Another possible disadvantage is that groundwater could be contaminated, but no more so than other infiltration practices.

Water Quality Inlets
(Oil and Grease Removal)

Water quality inlets are permanent storm water management control structures that remove sediment and hydrocarbons from urban storm water runoff (see Figure 20). Water quality inlets are typically the best management practice of preference when high volumes of vehicular traffic or high petroleum inputs are expected.

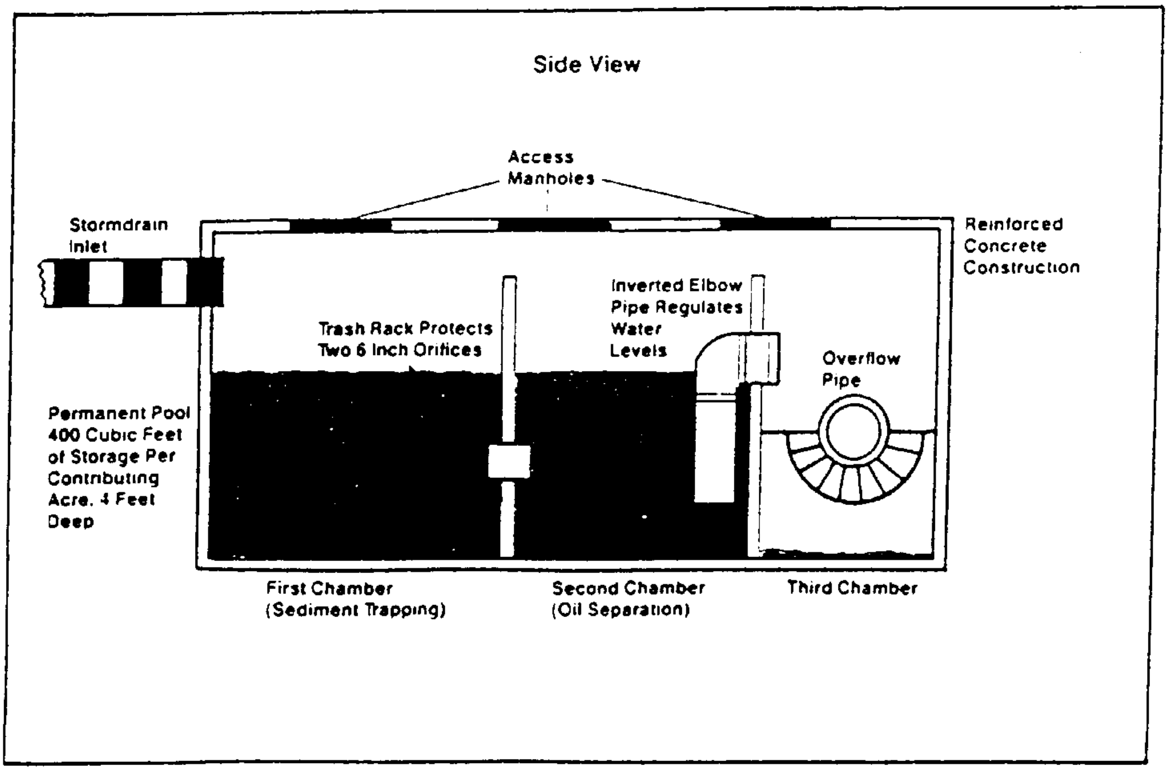

Figure 20. Schematic of Three Chamber Water Quality Inlet (Source: Schueler 1987)

Schueler (1987) expects that only moderate pollutant removal can occur because of the relatively short time the storm water runoff can be detained. Moderate removal efficiencies of coarse sediments, petroleum products, and debris is expected, but soluble or fine particulate pollutants are expected to pass through with minimal removal. Thus the water quality inlet is primarily a pretreatment to be used in conjunction with other best management practices.

Basic design practices dictate that a water quality control inlet should not differ from an ordinary storm water runoff control inlet (i.e. similar drainage area considering both percent impervious and slope of the drainage area). A cut off value of 1 acre is the typical maximum drainage area that can be treated by a water quality control inlet.

NURP did not address water quality inlets (USEPA 1983). Schueler (1987) states that the pollutant removal rates have never been tested in the field. Oil and grease are expected to be efficiently removed but generalizations regarding other pollutants cannot be made at this time.

Advantages of using water quality inlets as best management practices are that they reduce coarse sediment, debris, and hydrocarbon loadings that can clog, or fail, infiltration practices. Water quality control inlets can easily be incorporated into curb and gutter storm water management systems. These inlets are unique in that they can unobtrusively pre-treat storm water runoff before it enters other best management practices. Disadvantages include limited capability for pollutant removal, and the frequent clean out and disposal of accumulated pollutants is required.

Vegetative Systems

Vegetative Systems are vegetative areas, natural or engineered, that are established to enhance pollutant removal and habitat value (Schueler 1987). Natural vegetative areas are environmentally acceptable and aesthetically pleasing. Engineered vegetative areas are slightly less environmentally acceptable and aesthetically pleasing. Natural vegetative areas are difficult to incorporate into development designs because a natural vegetative area does not always exist where site demands dictate. This is why natural vegetative areas are prone to high failure rates. Engineered vegetative areas are easier to incorporate into development designs because of the flexibility associated with the placement of the vegetative area. Engineered vegetative systems provide more efficient removal of pollutants than natural systems. All vegetative systems typically have high failure rates because of the lack of proper maintenance and inspection. Examples of vegetative systems are grassed swales, filter strips, urban forest, basin landscaping (modification), and constructed wetlands (see Figure 21). Vegetative systems are not generally capable of entirely controlling increased storm water runoff (i.e. detention ponds and retention ponds) and/or the export of pollutants from a particular site but that they can improve the performance of other best management practices (Schueler 1987). Schueler and others, have indicated that vegetative systems should be an integral part of every development site.

The NURP did not completely access vegetative systems but indicated that additional study could substantially enhance performance capabilities (USEPA 1983). Three vegetative systems were studied, all grassed swales. Two swales failed to show any water quality enhancement. For the third swale, pollutant removal was about 50% for metals, and around 25% for COD, nitrate, and ammonia. Organic nitrogen, phosphorous, and bacteria were essentially unaffected (USEPA 1983).

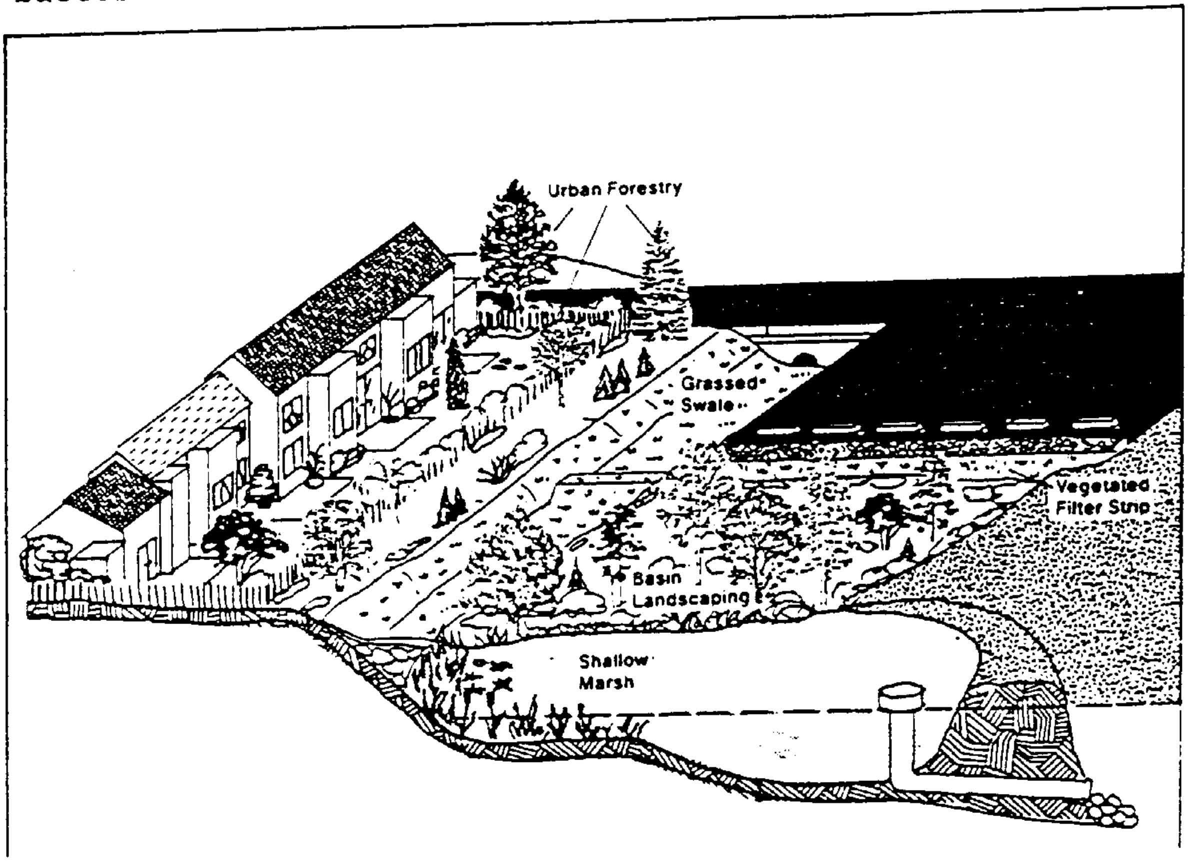

Figure 21. Schematic of Vegetative Systems
(Source: Schueler 1987)

Grassed Swales

Grassed swales are an excellent best management practices for developments zoned as single family residence (low density). Grassed swales are also used for the medians of highways. The use of grassed swales reduces impervious area (areas that would have been needed for curb and gutter systems), aids in slowing, or controlling, storm water discharges - which in effect lengthens the time of concentration. Time of concentration is defined as the time it takes a drop of rain to travel from the most remote point of the drainage basin to a downstream point of interest (i.e. an outlet).

Grassed swales benefit water quality by reducing storm water runoff velocities and potential scour, and the filtering of pollutants by the grass. Removal by infiltration, and sorption, is limited. OWML (1983) indicates that nutrient and trace metal export was slightly increased. Other studies (Kercher et al. 1983 and Yousef et al. 1985) indicated moderate to high removal of particulate pollutants. Schueler (1987) indicates that at least moderate removal of particulate pollutants can "more than likely" be expected during small storms.

There seems to be only limited consensus on the best roles and optimal design standards for swales. The combined effects of reducing impervious area, controlling storm water runoff, and improving water quality can all be incorporated in swale designs (see Figure 22). Some swales are designed only for controlling storm water. Others may be designed for improving water quality, while others may be designed to reduce impervious area. This high degree of variability in design masks the trapping efficiencies swales may actually have.

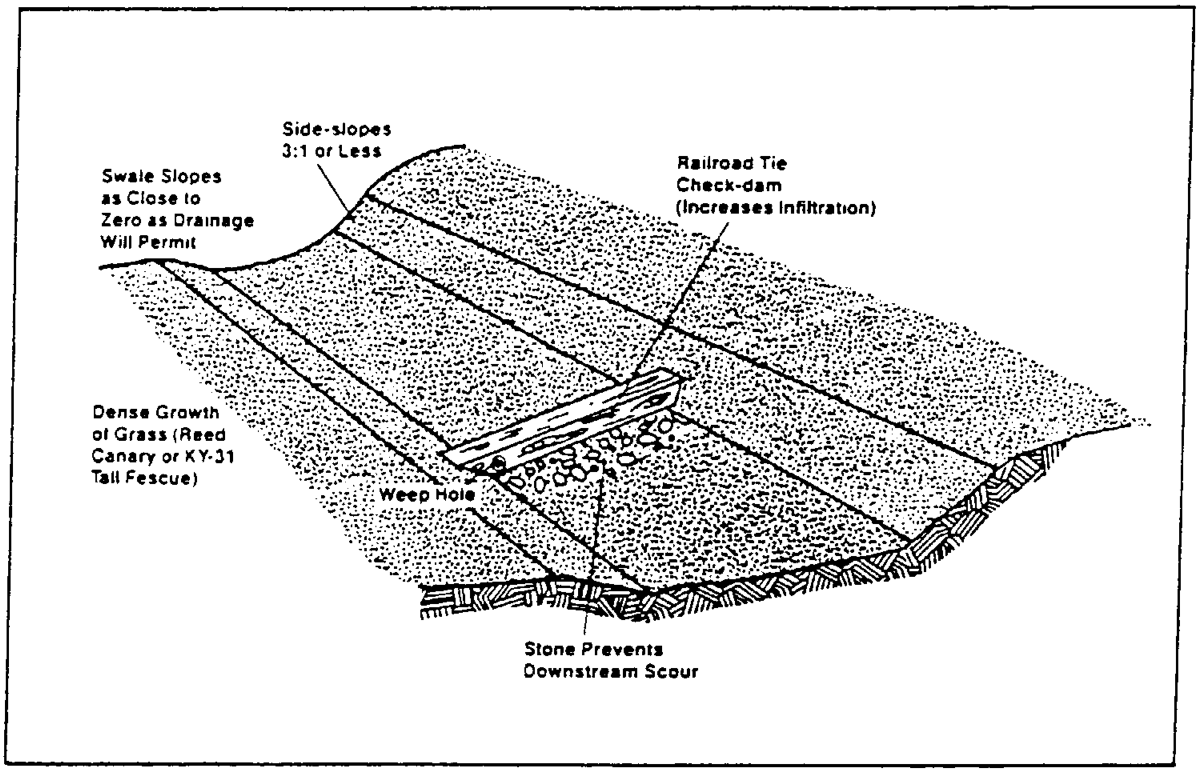

Figure 22. Schematic of Grassed Swale (Source: Schueler 1987)

Grassed swales are typically not recommended as best management practices if gradients of the swales exceed 5.0%, if the maximum velocity exceeds 3.0 feet per second, or if the peak runoff discharge rate exceeds 5.0 cubic feet per second. In most cases, it is recommended that other best management practices be used in combination with grassed swales (Schueler 1987).

A big advantage of using grass swales as a best management practices is that most maintenance on the swale is performed by the adjacent land owner. The maintenance would mainly consist of typical lawn care functions such as mowing, watering, and fertilizing so that a good stand of grass is maintained. However, landowners should be made aware that the grassed swale is not a "ditch". A disadvantage of using grass swales is that flow capacity is limited and storm water runoff from large design storms can cause brief, minor flooding. Grassed swales typically do not allow infiltration (Schueler 1987). Due partly to the fact that contact time in the swale is typically only 5 to 20 minutes and partly due to the fact that swales are heavily compacted, making for very slow infiltrating of water through the soil profile.

Filter Strips

Filter strips are useful for improving water quality, environmental habitat, and aesthetics of a development site. At this time the removal of pollutants by filter strips are not completely understood. Hayes and Dillaha have made recommendations on trapping efficiencies for sediment using vegetative filter strips (Hayes and Dillaha 1992 and Dillaha and Hayes 1992). Dillaha (1986) has also studied long term effectiveness and required maintenance. He suggest's that berms be placed at 50 to 100 feet intervals perpendicular to the top edge of the vegetative filter strips (see Figure 23).

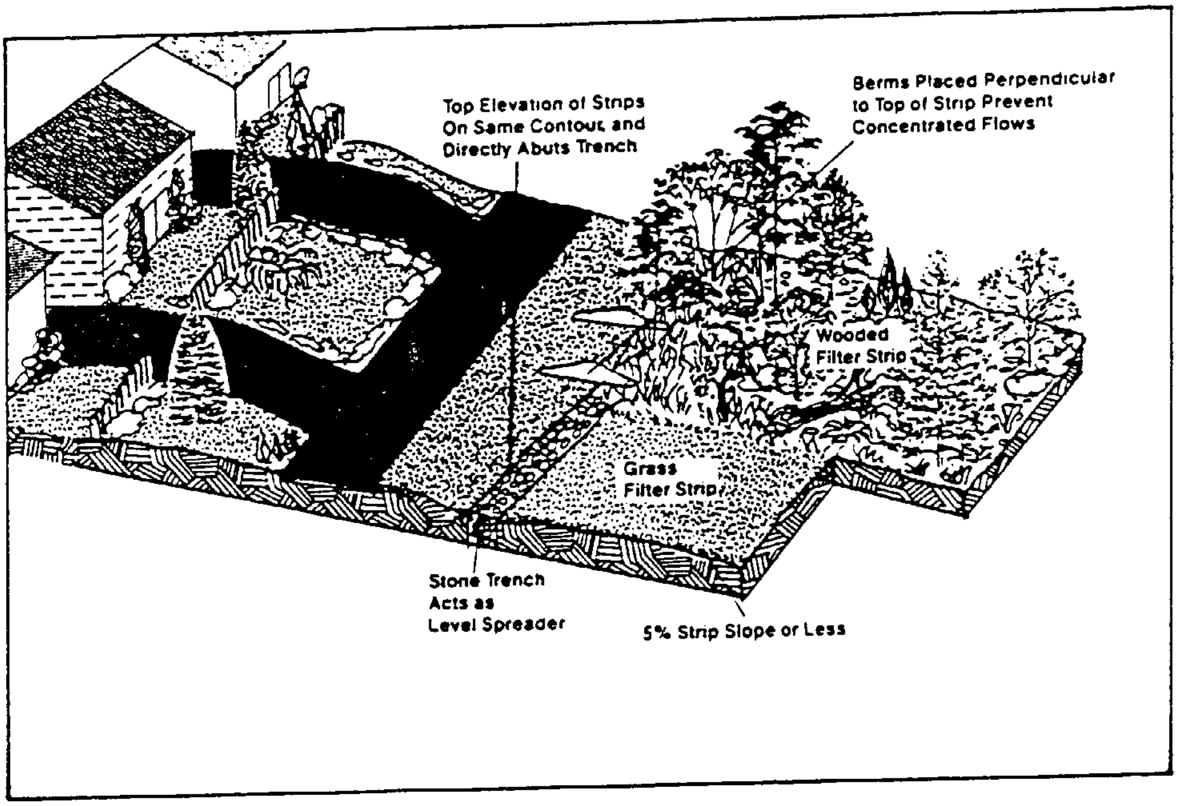

Figure 23. Schematic of Vegetative Filter Strip
(Source: Schueler 1987)

Barfield (1977) indicates that vegetative filter strips are effective in removing particulate pollutants such as sediments, organic materials and many trace metals. These test were conducted on small test plots and related to predicting the sediment transport in grass media. Schueler (1987) indicates that the rate of removal of pollutants is a function of the width, slope, soil type (permeability), size of the contributing drainage area, and the discharge velocity. Phillips (1988) has developed two equations to model the above parameters, using an "ideal filter strip" to determine widths required for buffer zones adjoining estuaries. One equation is based on hydraulics and the other equation is based on detention.

Vegetated filter strips can only be used for best management practices that allow the discharge to enter in a sheet flow manner. This is difficult to engineer, and thus represents a significant disadvantage. Vegetative filter strips are also not recommend to be the primary best management practice for areas greater than 5 acres (Schueler 1987). Vegetative filter strips must be periodically checked for short circuiting through or around the strip. Short circuiting of the vegetative filter strip virtually reduces any water quality enhancement.

Additional investigations of vegetative filter strips are proposed by McCutcheon, Hayes, and Klaine (1993). These investigators will evaluate the efficiency of vegetative filter strips to improve water quality.

Urban Forest

The best management practice, urban forestry, is primarily the landscaping of a development site. If landscape architects and engineers combine their skills to design and plan projects, a residential development consisting of trees and shrubs, and other ground cover can occupy 50% of the site (Schueler 1987). Increased vegetation decreases impervious and/or semi-impervious areas. With decreased impervious area, smaller runoff volumes are generated, and peak flow rates are lowered.

The water quality benefit from urban forest arises from pollutant removal taken up by the root systems, as well as reducing soil erosion. The overall amount of pollutant trapping varies and is poorly understood. Some air pollution can be reduced by urban forest. This could then reduce the pollutants falling from the atmosphere, which could indirectly improve water quality.

Urban forest require that proper planning be involved in the landscaping of residential lots or the residential community. It is not practical to use urban forest management practices for areas of a lot or residential community that contain play grounds or walking paths. These areas experience heavy foot traffic, which could cause erosion.

Urban forest are valuable in providing habitat environments for a variety of wildlife. Trees and shrubs provide a natural temperature buffer for thermal sensitive aquatic life. Trees and shrubs also help to control erosion. Disadvantages of urban forest could be recent concerns regarding the release of hydrocarbons from stands of pine trees in large Southern cities (i.e. Atlanta, Georgia). Schueler (1987) indicates that higher nutrient loadings could occur due to pollination, and/or autumn leaf falls

Basin Landscaping

The most important best management practice is basin landscaping (Schueler 1987). It is important for the designer to be familiar with the watershed that the development will impact and make use of the existing natural landscape (see Figure 24). Basin landscaping uses topography and vegetation to stabilize erosion due to storm water runoff and to improve water quality by reducing sediment loads and increasing the uptake of pollutants by the vegetation.

Basin landscaping is important in the design of all other best management practices. For example, the maintenance and operation of retention ponds can be greatly enhanced if proper basin landscaping exists. Aquatic plants can be grown near the shore line of the pond such that soluble pollutant removal is enhanced. A vegetative filter strip used as the inlet into the pond can be used to reduce entering storm water runoff velocities and initiate removal of the larger particulate pollutants.

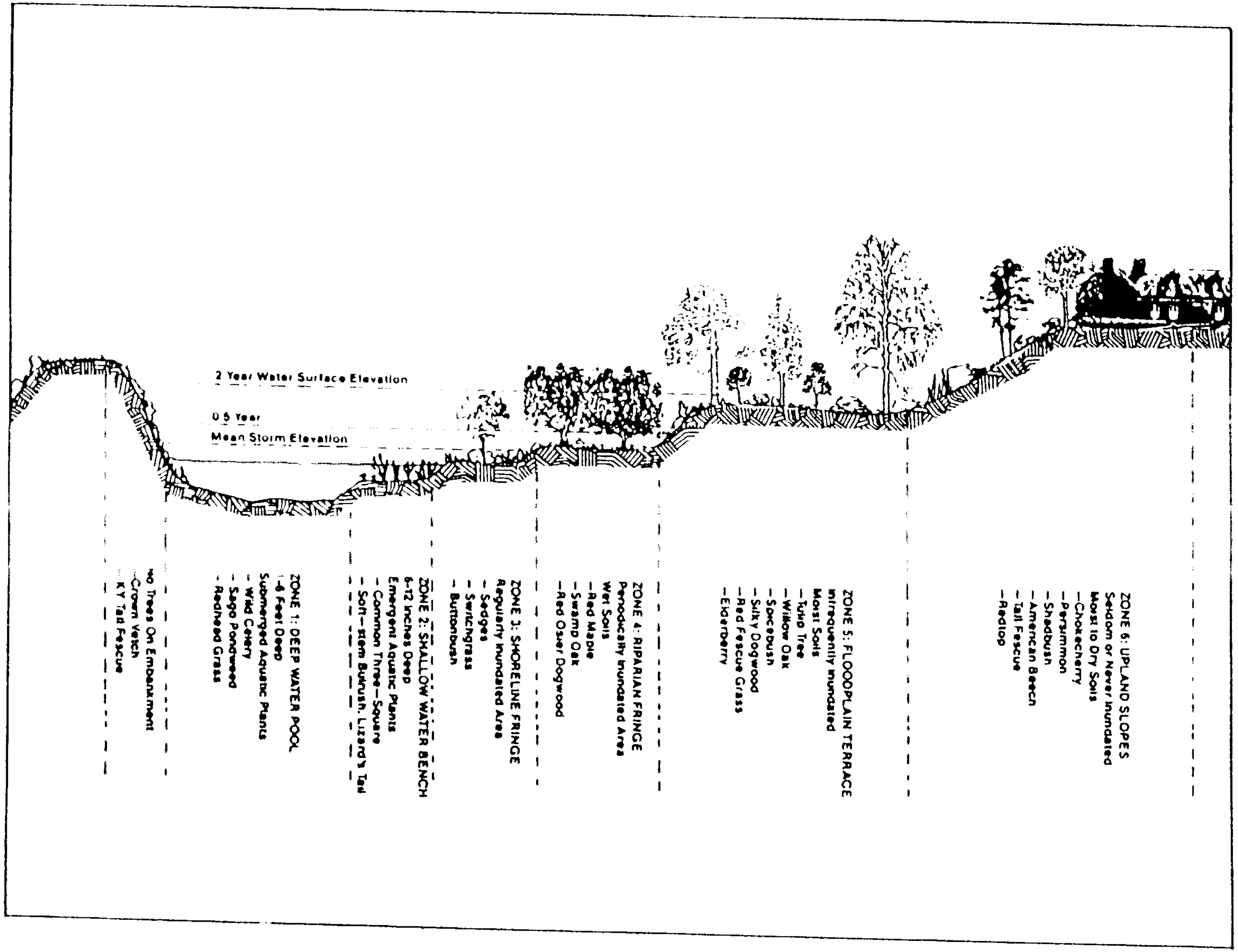

Figure 24. Basin Landscaping Zones for Watershed
(Source: Schueler 1987)

Constructed Wetland

The design of a shallow marsh (or constructed wetland) is very similar to basin landscaping. Again, topography and vegetation are essential in designing a constructed wetland. The best management practice of using a constructed wetland is defined as the creation of a marsh for the specific purpose of controlling storm water runoff and to improve the water quality leaving a development site. The use of constructed wetlands as a best management practice has numerous ecological and apparent water quality benefits but their trapping efficiency for specific pollutants has not been evaluated. The following guidelines should be considered for successfully establishing wetlands (Schueler 1987, Athanas 1986, Lakatos and McNemar 1986, and Maryland SCS 1986):

- Plant propagation is most reliable when live plants are transported from existing marshes or by using dormant rhizomes from nursery stock.
- Water depth must be maintained relatively constant so that the growth and colonization of the wetland will proceed naturally.
- Optimal nutrient removal occurs in shallower marshes.
- Surface area of the marsh, as a rule of thumb, should consist of 2% to 3% of the total surface area of the contributing drainage basin.
- Planting strategies should detail that at least two primary marsh plants (healthy and rapid colonizing to that drainage basin) should be planted alternatingly.
- At least three other secondary marsh plants should also be planted which will further increase the probability of successful establishment of a constructed wetland.

The primary disadvantages of constructed wetlands is that little is known about wetland hydrology and pollutant removal. It is therefore quite difficult for designers to incorporate existing or constructed wetlands into storm water management plans. There are also policy concerns regarding existing wetland use. Since the assimilative capacity of wetlands are difficult to determine, it would be best if storm water management plans were designed to use other best management practices - at least until research has unlocked these mysteries. For now, though, wetlands can act as a backup if other engineered management practices fail. Further, wetlands represent the habitats for numerous species and act to ensure the ecological dynamics of these species.

Wetlands destruction and use also requires extensive permitting. This permitting process can be stopped or slowed by citizen concerns. To avoid costly delays, engineers and landscape architects should fit developments around existing wetlands, provide best management practices to protect wetlands, and add wetlands only to ensure full protection of existing wetlands from increased storm water runoff. The involvement of organized environmental groups, concerned neighbors, and regulatory agencies in the planning stages of the development can identify impacts and reduce concerns.

Nonstructural Best Management Practices and Other Approaches

A nonstructural best management practice is a regulation or guideline that is enforced to improve water quality/quantity control. A typical nonstructural best management practice includes local storm water management, sediment, or erosion control ordinances (See also "Legal Aspects of Storm Water - Current Regulations" for SC's state wide plan). Other nonstructural best management practices involve education regarding the disposal of hazardous waste (household cleaning supplies, grease and oil, etc.). Other programs could involve the disposal, application, or handling of pesticides, herbicides, and fertilizers. Nonstructural best management practice could also include an ordinance for disposal of pet wastes.

Other best management practices that do not fit in the category of structural, nor in the nonstructural best management practices, include rock check dams, silt fences, hay bales, quick growing grasses, stone drive pads for entering and leaving construction sites, and many more can be used effectively to control storm water runoff and manage erosion. An excellent source for these types of practices can be found in the **Virginia Erosion and Sediment Control Handbook 1991**, or the most current edition (VA SCS 1991). This handbook provides design drawings, standards and specifications, and maintenance schedules. South Carolina's handbook (SCLRCC 1985) is somewhat out of date, but does contain some of the same information.

One other of these "non category" best management practices, street sweeping, has been studied to determine its effectiveness at improving water quality. NURP conducted studies on street sweeping and found that no water quality enhancement was achieved and in some sites water quality was actually degraded by the street sweeping practice (USEPA 1983). American Public Works Association (APWA 1991) confirms this finding and indicated that some municipality sweep operators swept debris into the nearest catch basin. It should be noted that street sweeping is an aesthetically pleasing management practice but it can be detrimental to water quality. Street sweeping should be viewed as a service to maintain the quality of life, and not included in storm water management plans or polices, except to note that additional treatment may be needed to accommodate the sweeping.

SUGGESTIONS FOR SOUTH CAROLINA AND THE COAST

Pursuant to the South Carolina Coastal Zone Act, the South Carolina Coastal Council (SCCC) was vested the authority to manage coastal development. SCCC gained authority over all land disturbing activities along coastal South Carolina pursuant to the Storm Water Management and Sediment Reduction Act of 1991, established in the South Carolina **State Register** June 26, 1992. The South Carolina Land Resource Conservation Commission (SCLRCC) was granted authority over all other land disturbing areas.

SCCC has published Storm Water Management Guidelines (September 1, 1988), Proposed Refinements to the Management Program Document, Certification Process (October 21, 1992), Regulations for Permitting in Critical Areas of the State's Coastal Zone (May 1991), and Guidelines and Policies of the South Carolina Coastal Management Program (NA-79-AA-D-CZ126). The SCCC also references the SCLRCC publications Erosion and Sediment Control Practices for Developing Areas (1985) and A Guide to Site Development and Best Management Practices for Storm Water Management and Sediment Control (1991). At the time, these documents were written using solid engineering judgement and more than adequate research to support their conclusions. In subsequent revisions of SCCC (1988), SCCC (1991), SCCC (NA-79-AA-D-CZ126), SCLRCC (1985), and SCLRCC

(1991), new and innovative designs (or practices) should be incorporated.

The innovations are available from research that the South Carolina Department of Health and Environmental Control (SCDHEC), SCCC, SCLRCC, and the Charleston Harbor Project has funded. If a committee could be formed that would share this combined research base, the most technically innovative, environmentally sound, and economically reasonable documents and guidelines could be drafted. The combining of some of these documents would allow design engineers and reviewers to have a single document to follow as a guide. This would produce better plans that were easier to review.

DESIGN AIDS

The following tables were created to aid in the selection of best management practices. Table II lists restrictions that are critical in choosing best management practices. Table III lists the relative benefits provide by best management practices. Table IV lists the comparative pollutant removal capabilities provided by best management practices. Table V lists relative environmental and community amenities provided by best management practices. Table VI provides basic design summaries for each best management practice.

Table II

Site Restrictions
on Urban Best Management Practices
(modified from Schueler 1987)

Best Management Practice	Slope	Water Table	Bedrock	Space Consumption	Maximum Depth	High Sediment Input	Thermal Impacts
Detention Pond	N	N	S	A	N	S	N
Retention Pond	N	N	S	A	A	S	A
Infiltration Basin	A	A	A	N	A	A	N
Infiltration Trench	S	A	A	S	A	A	N
Porous Pavement	A	A	A	A	A	A	N
Water Quality Inlet	N	N	A	N	A	A	N
Grassed Swale	A	A	S	N	N	A	N
Filter Strip	S	S	S	N	N	A	N

N = Generally not restrictive
S = Sometimes restrictive
A = Always restrictive

Table III

Comparative Storm Water Benefits Provided
by Urban Best Management Practices
(modified from Schueler 1987)

Best Management Practice	Control 2-yr. Storm	Control 10-yr. Storm	Control 100-yr. Storm	Volume Control	Groundwater Recharge	Streambank Erosion Control
Detention Pond	A	A	A	N	N	A
Retention Pond	A	A	A	N	N	A
Infiltration Basin	A	S	N	A	A	A
Infiltration Trench	A	S	N	A	A	A
Porous Pavement	A	S	N	A	A	A
Water Quality Inlet	N	N	N	N	N	N
Grassed Swale	S	N	N	S	S	N
Filter Strip	S	N	N	S	S	N

N = (Never) seldom beneficial
S = Sometimes beneficial
A = (Always) usually beneficial

Table IV

Relative Pollutant Removal of
Urban Best Management Practice Designs
(modified from Schueler 1987)

Best Management Practice	Suspended Sediments	Total Phos-phorus	Total Nitrogen	Oxygen Demand	Trace Metals	Bacteria	Overall Removal Capacity
Detention Pond Design 1/2/3	B/A/A	D/C/B	D/D/C	D/C/C	C/B/B	IK/IK/IK	M/M/H
Retention Pond Design 4/5/6	B/B/A	C/C/B	D/D/C	D/D/C	D/B/B	IK/IK/IK	M/M/H
Infiltration Basin Design 7/8/9	B/A/A	C/C/B	C/C/B	B/B/A	C/A/A	B/B/A	M/H/H
Infiltration Trench Design 7/8/9	B/A/A	C/C/B	C/C/B	B/B/A	B/A/A	B/B/A	M/H/H
Porous Pavement Design 7/8/9	C/A/A	B/B/B	C/B/B	B/B/A	C/A/A	B/A/A	M/H/H
Water Quality Inlet Design 10	E	IK	IK	IK	IK	IK	L
Grassed Swale Design 11/12	E/D	E/D	E/D	E/D	E/D	IK/IK	L/L
Filter Strip Design 13/14	D/A	E/C	E/C	E/B	D/A	IK/IK	L/M

E = 0-20%   D = 20-40%   C = 40-60%   B = 60-80%   A = 80-100%   IK = Insufficient Knowledge
H = high   M = moderate   L = low
Note: Design numbers are described on the following page.

Notes for Table IV
(modified from Schueler 1987)

Design 1: First-flush runoff volume detained for 6-12 hours.
Design 2: Runoff volume produced by 1.0 inch, detained for 24 hours.
Design 3: Same as Design 2, but with shallow marsh in bottom stage.
Design 4: Permanent pool equal to 0.5 inch storage per impervious acre.
Design 5: Permanent pool equal to 2.5 times the mean storm runoff.
Design 6: Permanent pool equal to 4.0 times the mean storm runoff.
Design 7: Facility exfiltrates first-flush; 0.5 inch runoff/impervious acre.
Design 8: Facility exfiltrates one inch runoff volume per impervious acre.
Design 9: Facility exfiltrates all runoff, up to the 2 year design storm.
Design 10: 400 cubic feet of wet storage per impervious acre.
Design 11: High slope swales with no check dams.
Design 12: Low gradient swales with check dams.
Design 13: 20 foot wide turf strip.
Design 14: 100 foot wide forested strip with level spreader.

Table V

Environmental and Community Amenities
Provided by Urban Best Management Practices
(Source: Schueler)

BMP	LOW FLOW MAINTENANCE	STREAMBANK EROSION CONTROL	AQUATIC HABITAT CREATION	WILDLIFE HABITAT CREATION	NO THERMAL ENHANCEMENT	LANDSCAPE ENHANCEMENT	RECREATIONAL BENEFITS	HAZARD REDUCTION	AESTHETICS	COMMUNITY ACCEPTANCE
DRY EXTENDED DETENTION	○	●	◑	●	●	◑	◑	◑	◑	◑
EXTENDED DETENTION w/ MARSH	○	●	●	●	○	◑	○	◑	◑	◑
WET EXTENDED DETENTION	○	●	●	●	○	●	●	◑	◑	●
WET POND	○	○	●	●	○	●	●	◑	◑	●
INFILTRATION TRENCH	●	◑	○	○	●	○	○	●	○	●
INFILTRATION BASIN	●	◑	○	●	●	◑	◑	●	○	◑
POROUS PAVEMENT	●	◑	○	○	●	○	○	●	○	●
WATER QUALITY INLET	○	○	○	○	●	○	○	●	○	●
GRASSED SWALE	◑	○	○	◑	●	◑	○	●	◑	●
FILTER STRIP	◑	○	○	●	●	◑	○	●	◑	●
SHALLOW MARSH	○	○	●	●	○	◑	○	◑	◑	◑

○ SELDOM PROVIDED

◑ SOMETIMES PROVIDED (w/ Design Modifications)

● USUALLY PROVIDED

Table VI

Design Summary
of Urban Best Management Practices

Best Management Practice	Area Served (Acres)	Soil Type (Infiltration rate) (in/hr)	Depth to Water Table (ft)	Recommended Minimum/ Maximum Storage time (hrs.)	Slope	Typical Design Method
Detention Pond						
Retention Pond						
Infiltration Basin						
Infiltration Trench						
Porous Pavement						
Water Quality Inlet						
Grassed Swale						
Filter Strip						

*** To be filled in when more literature arrives.

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